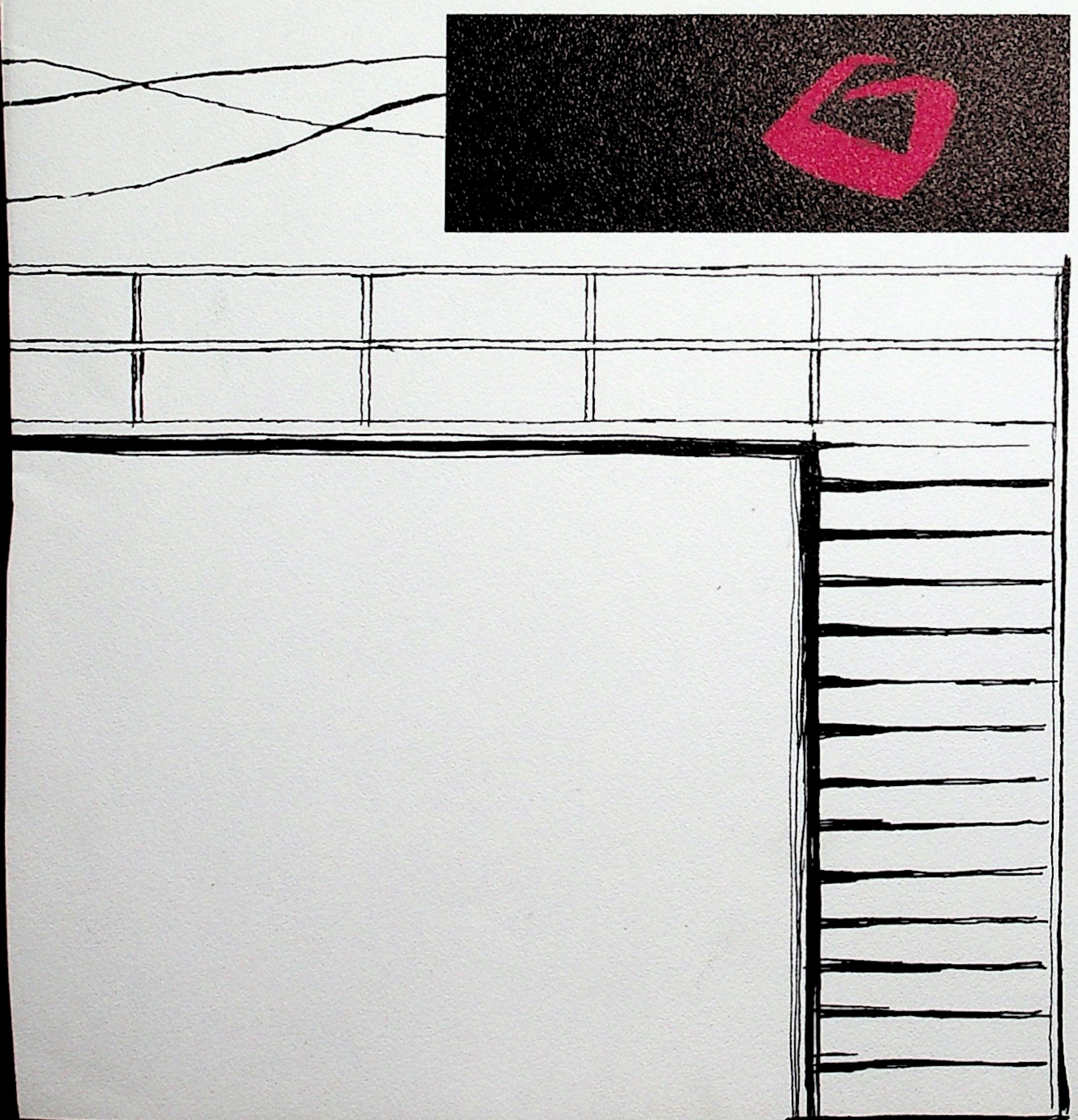


The Armour research reactor, located at Armour Research Foundation of Illinois Institute of Technology in Chicago, is the first nuclear research reactor designed particularly for peacetime use by private industry. Designed and built by Atomics International, a division of North American Aviation, Inc., this reactor opens up an entirely new field in industrial research by providing a continuous on-the-spot source of neutrons and high-energy gamma rays and by making readily available a supply of useful radioisotopes.

Standing as the culmination of an extensive research and development program initiated over a decade ago by Atomics International, the Armour research reactor represents a major advance in the field of organized industrial research.


5 TON

ARMOUR REACTOR

The Armour research reactor is a homogeneous solution type reactor, designed to operate at 50 kilowatts and to produce a maximum thermal neutron flux of about 1.7×10^{12} neutrons/cm^2-sec at the center of the reactor core. The design of the reactor is based upon experience obtained in the construction and operation of the Atomics International Water Boiler Neutron Source at Downey, California and the Livermore Research Laboratory Water Boiler at Livermore, California, which was built by Atomics International and is now operated by the University of California at Berkeley.

The reactor consists of a core assembly; gas-handling, fuel-handling, and cooling systems; a control and safety rod system; a reflector assembly; and the necessary instrumentation and shielding for safe and efficient operation. In addition, exposure facilities are provided through which neutrons and gamma-rays are available in various intensities for experimental purposes.

The core assembly contains the fuel, which serves as the primary power source, and the moderator, which controls the neutron speed. The fuel consists of enriched uranium, in the form of uranyl sulphate, dissolved in ordinary water, which serves as the moderator. The gas-handling system is used for confining and controlling the atmosphere within the core. The fuel-handling system provides a means of filling and draining the core tank. The cooling system maintains the core and recombiner temperatures at their proper values. The reflector assembly, which consists of graphite bars surrounding the core tank, increases the efficiency of operation by reflecting neutrons back into the reactor core.

The shielding consists of dense concrete which surrounds the entire reactor structure. This shielding serves to reduce the radiation level at all points exterior to the shield to a value which is less than one-tenth of the generally accepted safe dosage rate specified for laboratories handling radioactivity.

The control and safety rod system consists of four boron carbide cylinders which are positioned within the reactor core by appropriate control mechanisms and circuitry. These rods absorb neutrons and thus control the intensity of the fission reaction.

The instrumentation system consists of instruments and associated circuitry for monitoring reactor operation and power output. The system provides a continuous check on all reactor operations and ensures that all operating safety requirements are satisfied.

REACTOR DESCRIPTION AND OPERATION

CHARACTERISTICS OF ARMOUR REACTOR

Design Power	50 kw
Zero Power Critical Mass*	850 gm U^{235}
Maximum Thermal Neutron Flux	$1.7 \times 10^{12} n/cm^2$-sec
Mass Coefficient of Reactivity*	0.031%/gm
Temperature Coefficient of Reactivity*	—0.029%/°C
Power Coefficient of Reactivity*	—0.006%/kw
Fuel Solution Temperature at 50 kw*	80°C
Excess Reactivity at 20°C, Zero Power*	3%
Reactivity Held in Control and Safety Rods*	8% (2% each rod)
$H:U^{235}$ Atomic Ratio*	350
U^{235} Concentration*	75 gm/liter
Power Density, Maximum	5.5 watt/cm^3
Power Density, Average	3.85 watt/cm^3

*Approximate Value

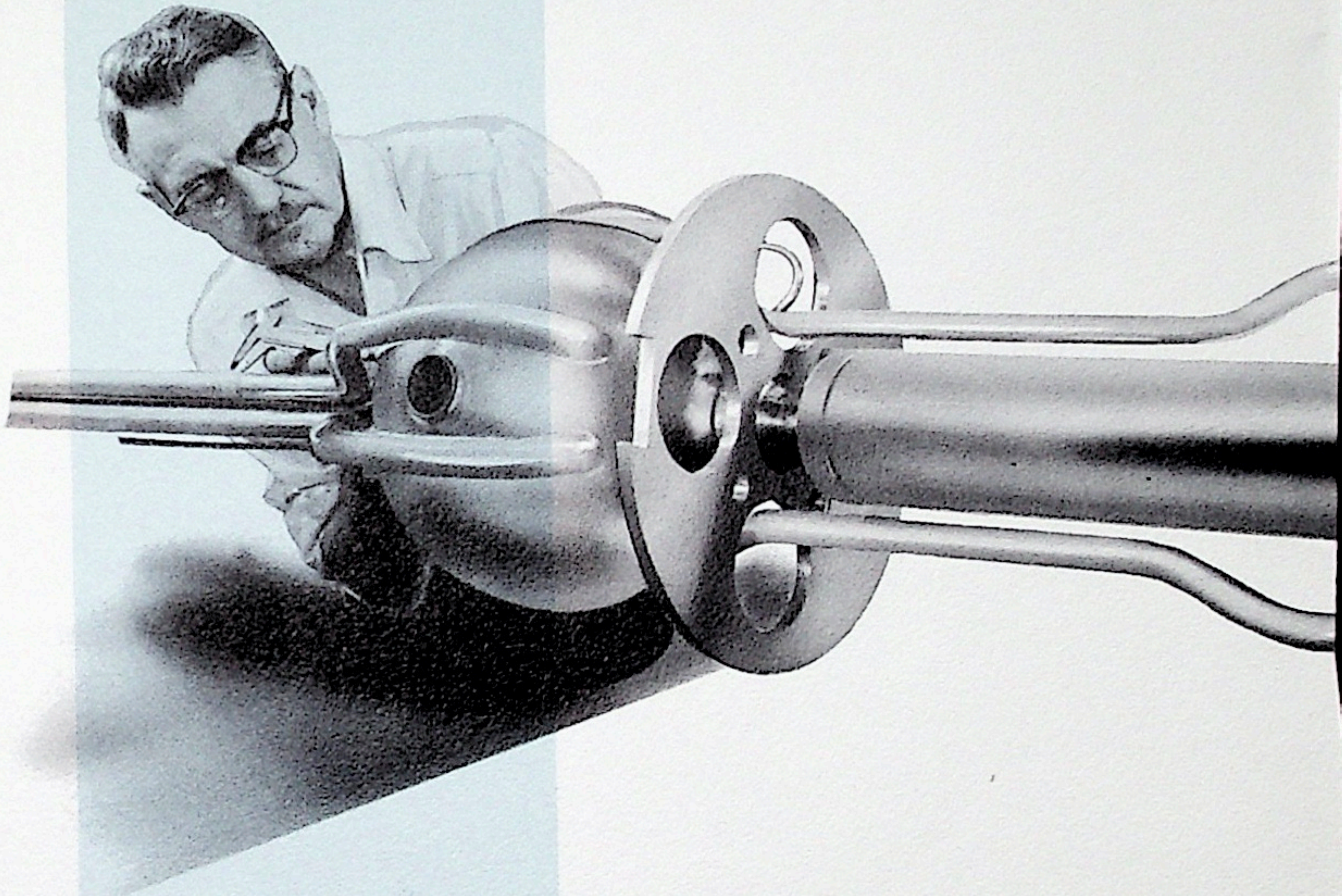
(1) DRIVE MOTOR
(2) CONCRETE SHIELDING
(3) CONTROL RODS
(4) GRAPHITE REFLECTOR
(5) MOVABLE CONCRETE DOOR
(6) REACTOR UTILITY ROOM
(7) CONTROL ROOM
(8) NEUTRON EXPOSURE FACILITY
(9) REACTOR CORE

REACTOR CORE

The reactor core assembly includes a spherical stainless-steel tank containing four control-rod thimbles which project vertically into the tank, a central exposure tube which extends horizontally through the center of the tank, cooling coils, a line for filling and draining fuel solution, and a gas outlet tube leading to the solution overflow tank and the gas-handling system.

The core tank contains a solution of enriched uranium, consisting of UO_2SO_4 dissolved in light water. Approximately 850 grams of U^{235} are required for a zero power critical condition. An additional 100 grams of U^{235} are required to compensate for temperature and power coefficients, voids within the core, and exposure of absorbing materials in or near the core. This additional fuel corresponds to an excess reactivity of approximately 3 per cent at zero power and room temperature.

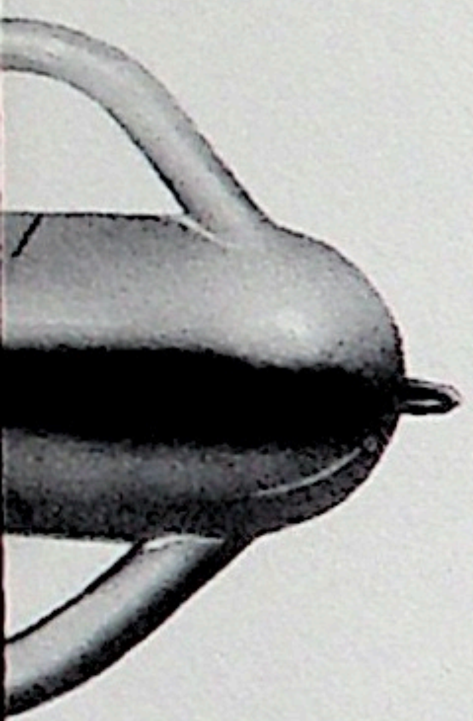
A solution overflow tank is connected directly above the core tank to contain any fuel solution which might be forced out of the core tank by radiolysis during a power surge. The fuel solution is forced up through the standpipe into the overflow tank and then slowly drains back into the core tank through a small opening in the bottom of the overflow tank. Approximately two liters of solution can be expelled from the core tank into the overflow tank; this amount is sufficient to reduce the core to a subcritical condition.



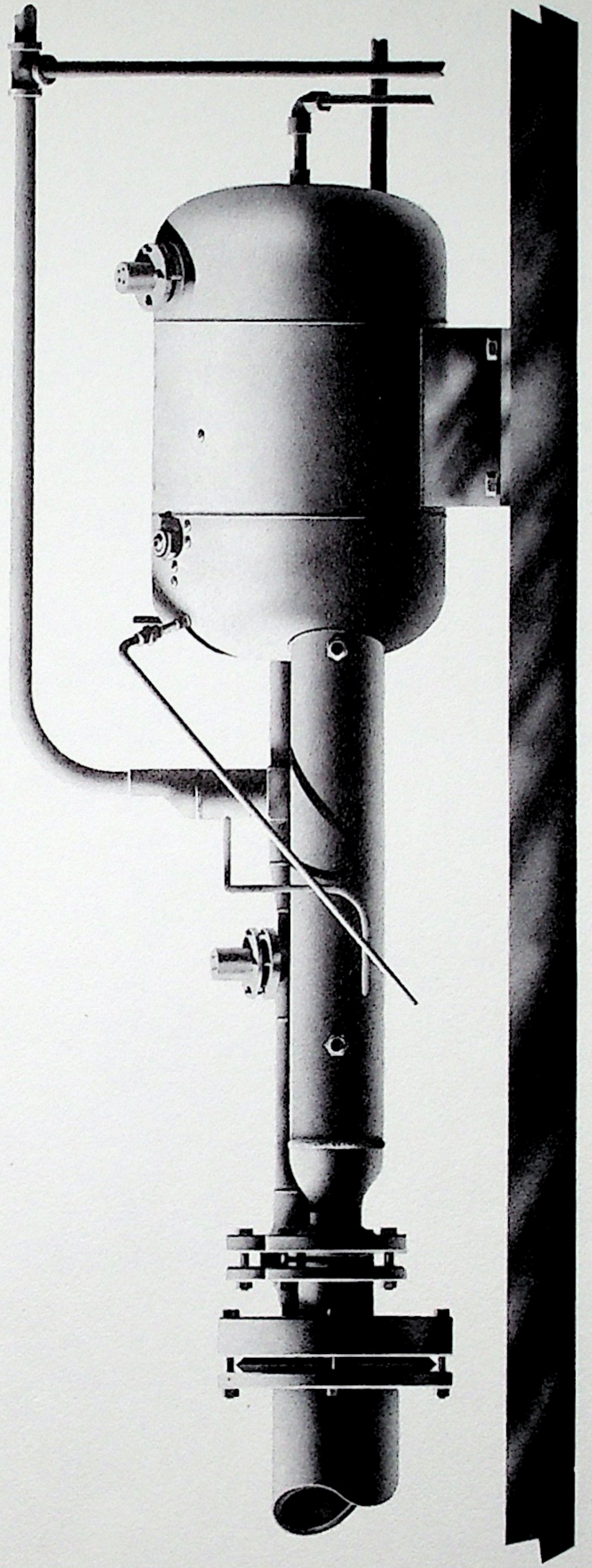
GAS HANDLING SYSTEM

The gaseous atmosphere above the fuel solution, which consists of water vapor, gaseous fission products, hydrogen, and oxygen, is controlled and processed in a closed system referred to as the gas-handling system. The principal functions of this system are (1) to recombine the hydrogen and oxygen which is produced by radiolysis of the solution water and return the resulting water to the core tank, and (2) to confine the radioactive fission-product gases and provide for their disposal.

The system consists essentially of the recombiner assembly, which is located below the reactor in the subpile room, and piping connecting the recombiner to the core tank. The system is initially charged with oxygen, which serves as the carrier gas during operation and aids in effecting the water-recombining process. To maintain atmospheric circulation within the system, a pressure differential is created by circulating water through an injector type nozzle. The circulating water passes from the recombiner tank through a heat exchanger, a water pump, the nozzle, and back into the recombiner tank. The heat exchanger operates from the core-cooling system and maintains the recombiner tank water at less than 122°F (50°C). The pump is a canned-rotor type and is provided with water-lubricated bearings.

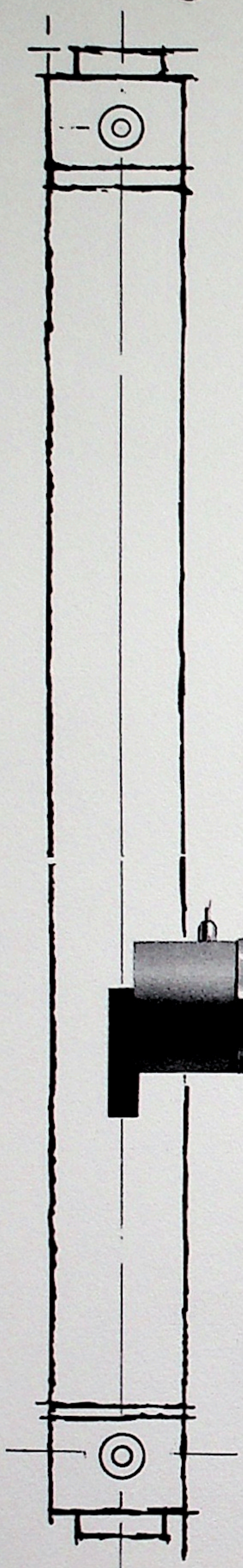


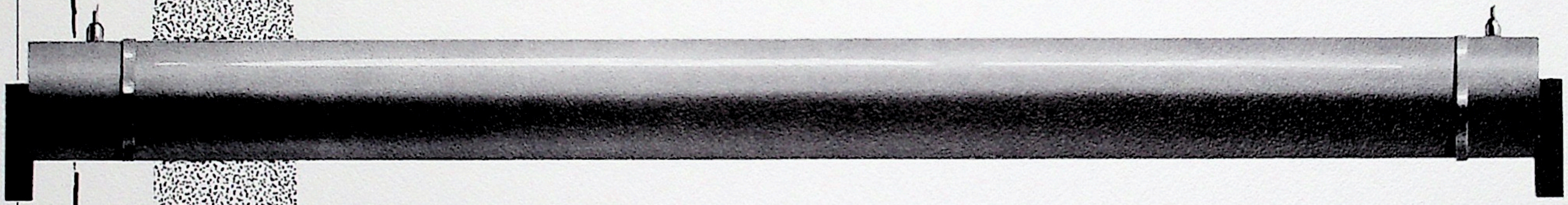
As the hydrogen and oxygen are produced in the core, they rise through the overflow chamber and an entrainment eliminator and are carried by the gas stream down into the sump below the reactor. After passing through two additional entrainment eliminators, the gases pass through the recombination chamber, which is a tank filled with small alumina cylinders coated with a platinum catalyst. This chamber is provided with a heater which maintains the temperature above 100°C to prevent condensation of water. Downstream from the recombination chamber, the reconstituted water vapor is condensed and swept back to the core by the carrier gas, whose flow rate is about 8 cubic feet/minute. The returning water drips into the spillover tank at the top of the core assembly, washing down both the entrainment eliminator and the core tank walls before reaching the fuel solution.



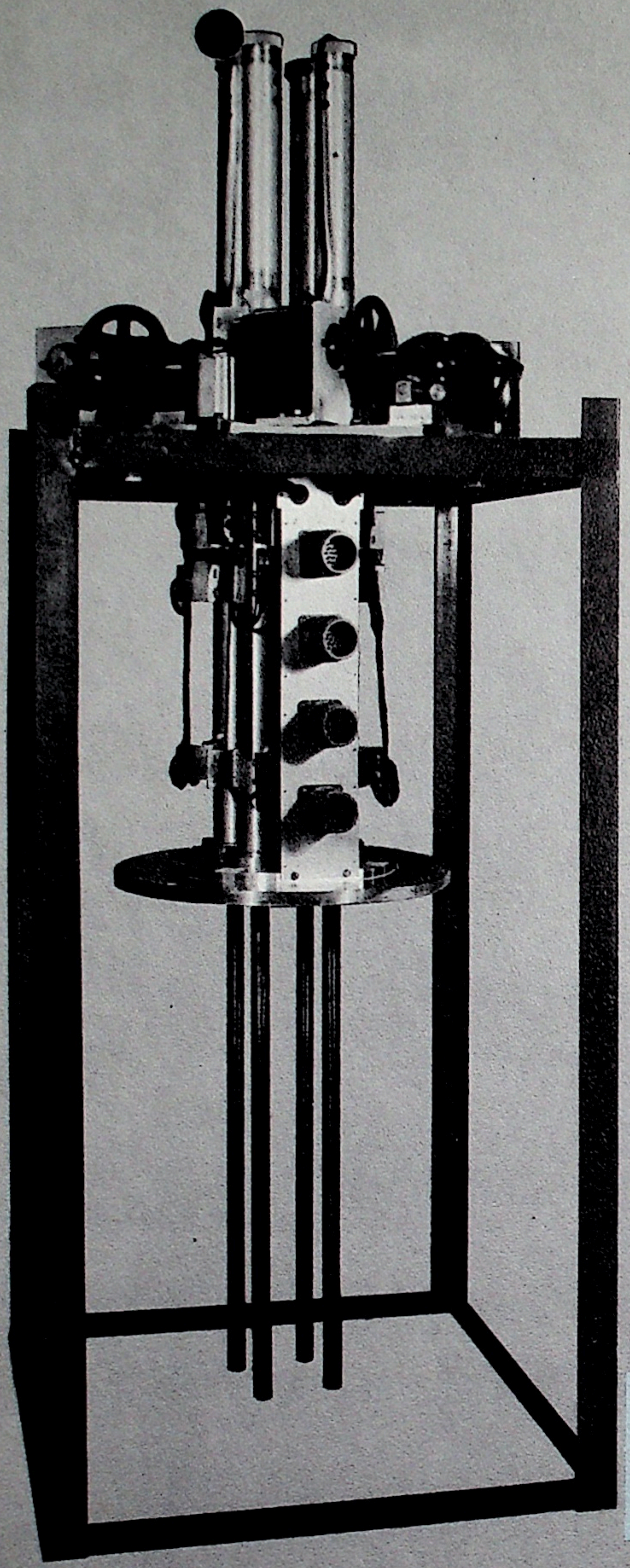
The fuel-handling system consists of a safe-geometry fill-and-storage tank located in the gas-tight subpile room below the reactor, and the piping and valving connecting the tank to the reactor core and to the external servicing connections. The tank, which is shielded by lead bricks, is designed for complete subcriticality and is of sufficient size to contain all of the core solution.

External connections for flushing the system and for venting both the core tank and the fill-and-storage tank are located in the exposure room. Shut-off valves in the lines leading to these connections are located in the subpile room and can be remotely operated from the valve room. Fuel solution can be transferred from the fill-and-storage tank to the core tank by pressurizing the fill-and-drain tank and venting or evacuating the core tank. The core tank can be completely drained by evacuating the fill-and-storage tank and venting or, if necessary, pressurizing the core tank.





FUEL HANDLING

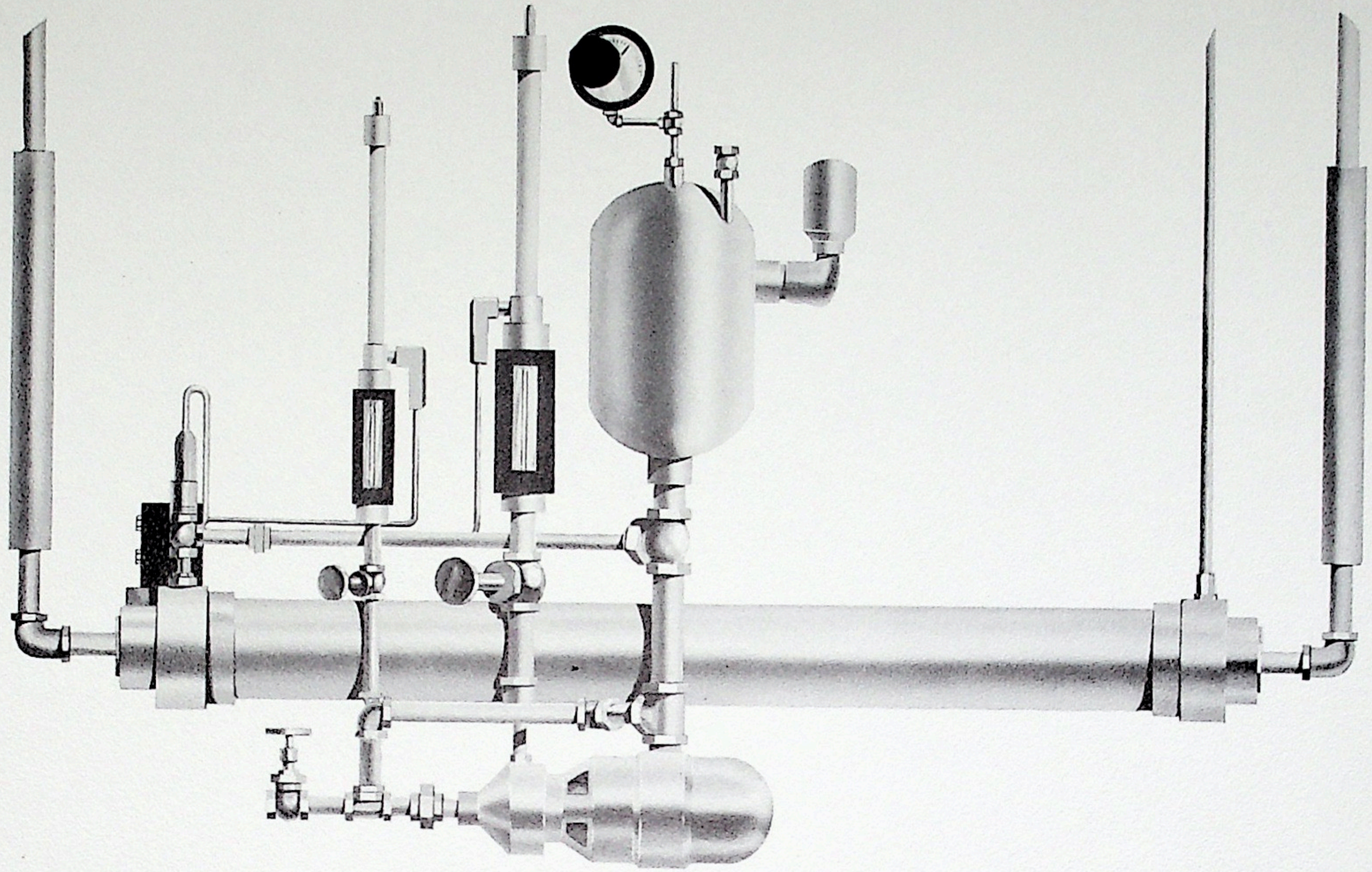


Four control rods are provided for power-level regulation and control of the reactor. Each rod controls approximately 2 per cent reactivity, making a total reactivity control of 8 per cent. Each rod, which consists of a boron carbide cylinder encapsulated in stainless-steel tubing, is oriented vertically in such a way that it may be inserted into or withdrawn from a vertical guide tube extending within the core tank.

The rod-drive mechanism is of the rack-and-pinion type, actuated through a gear-reduction unit by an electric motor. The rod travel is about 12 inches and the rate of withdrawal is about 0.1 inch/second. The drive mechanism and the control rod itself are separate parts held together by a direct-current electromagnet located at the bottom of the drive mechanism. When the magnet is de-energized, the rod falls freely by gravity for about 10 inches and then is decelerated by the air-cushioning effect for the remaining distance. The rods are 85 per cent effective when deceleration is initiated. The magnets are de-energized automatically by action of any of the reactor scram circuits or by power failure, and they may be de-energized manually at the control console.

Reactor power level can be controlled by automatic or by remote-manual operation of the control rods. One of the four rods is driven by a servo-controlled motor and functions as the automatic regulating rod. For normal startup, one of the rods is completely withdrawn from the core to serve as a safety rod; the reactor is then brought up to power by remote-manual withdrawal of the other rods to the required height. After the reactor power has been adjusted to the desired value by the operator, the automatic regulating rod is switched to automatic control, so that it serves to maintain the power level at a constant value.

CONTROL AND SAFETY ROD SYSTEM



COOLING SYSTEM

The reactor cooling system comprises a primary coolant pump, the main heat exchanger, the recombiner heat exchanger, the core cooling coils, and the necessary piping and valving.

The primary coolant, distilled water, is continuously circulated through the primary cooling section by the primary coolant pump, which is a motor-driven, constant-speed, centrifugal pump. Most of the coolant is circulated through the core cooling coils, which consist of 10 sections of stainless-steel tubing connected in parallel within the core tank. A small amount of coolant bypasses the core and is routed through the recombiner heat exchanger. Heat energy is removed from the core tank and recombiner by the primary coolant, which is distilled water. The heat energy is then transferred in the main heat exchanger to the secondary coolant, which is ordinary city water. The secondary coolant is completely isolated from the primary coolant water, and hence from any radioactivity. However, the secondary coolant is continuously monitored so that if a malfunction occurs in the cooling system, it can be closed off from the city water and sewage system.

A five-gallon surge tank, connected into the primary cooling section on the inlet side of the pump, serves as the coolant reservoir and provides expansion space for the primary coolant. Provision is made for venting and purging the system, when necessary.

REFLECTOR

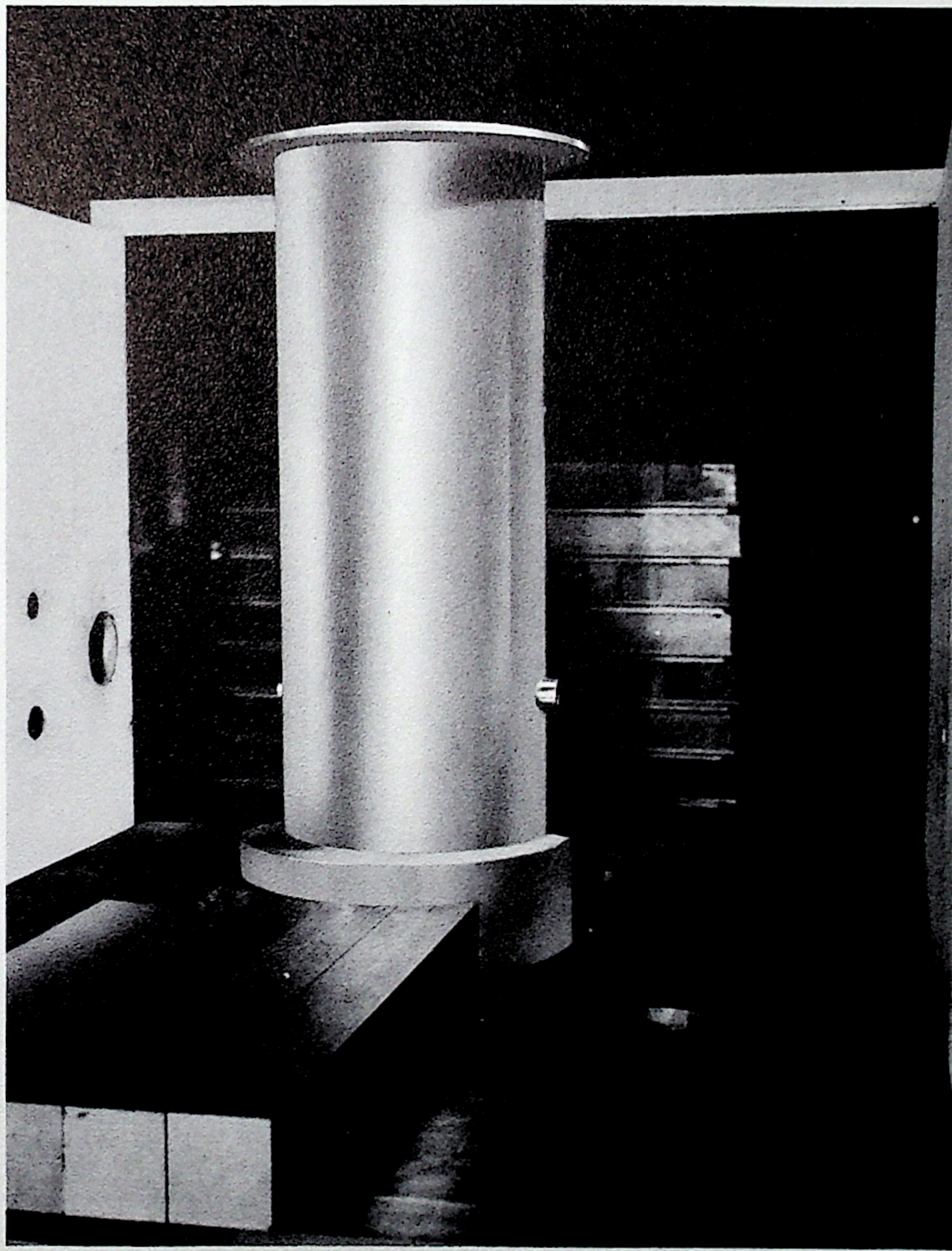
The reflector consists of a stack of graphite blocks which completely surrounds the core assembly. The blocks are four inches square and up to 50 inches in length, except for the pieces immediately surrounding the core assembly, which are of various shapes and sizes.

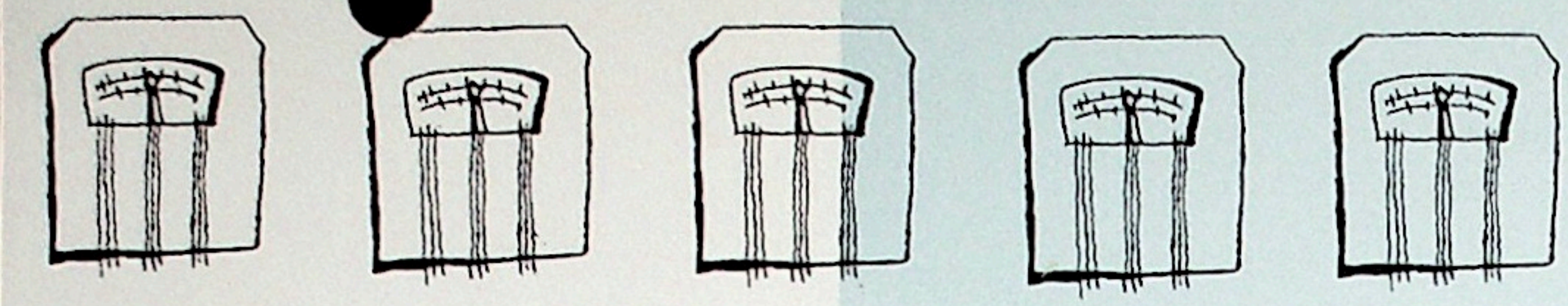
The irregular pieces are located within an aluminum cylinder which immediately surrounds the core assembly. The remainder of the pieces, which are located exterior to the aluminum enclosure, are stacked in 15 layers to form a rectangular prism about 6½ by 5 by 5 feet. The entire assembly is enclosed in a steel shielding tank.

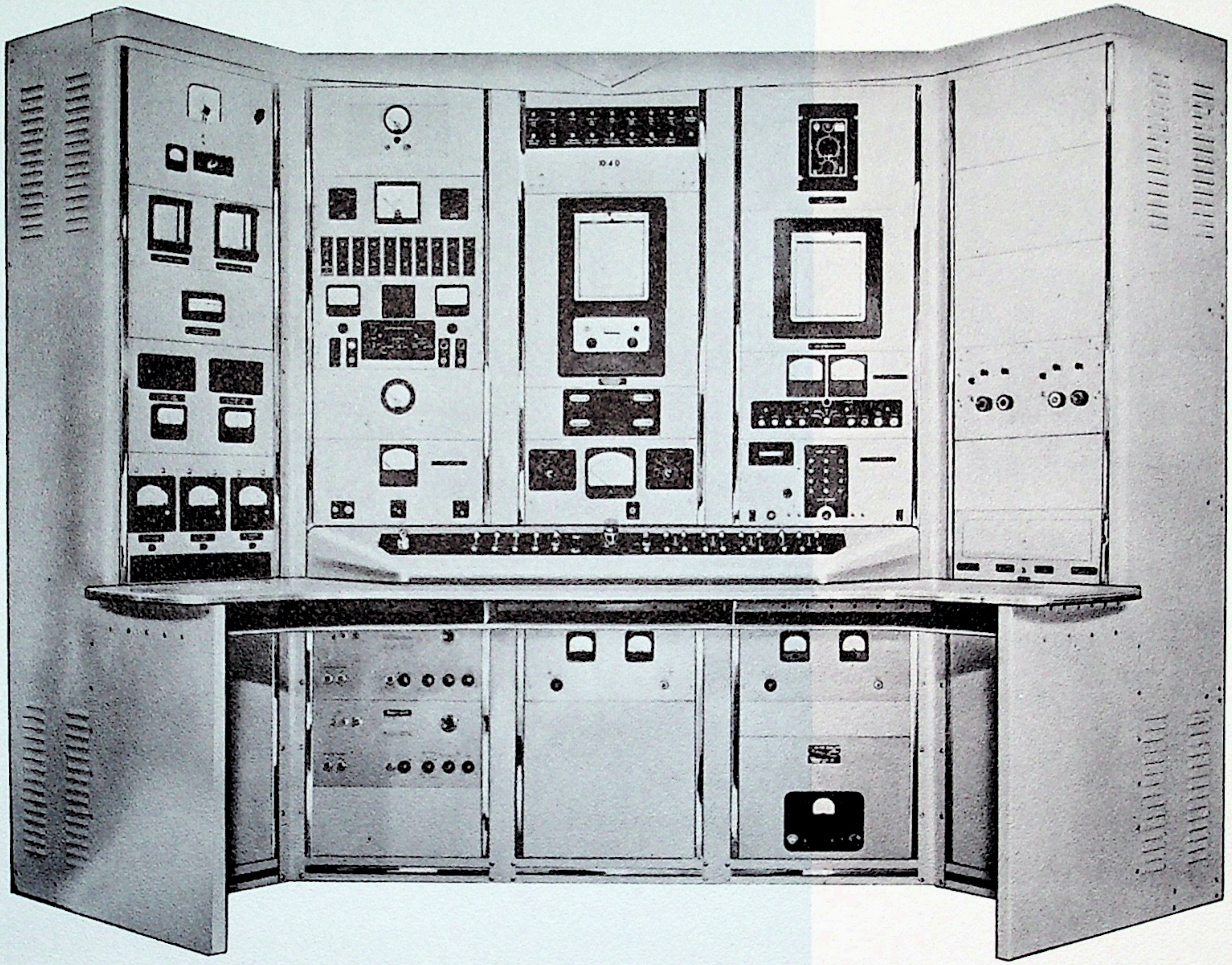
SHIELDING

Shielding for the reactor is provided by a five-foot thick biological shield of dense hematite-colemanite concrete which surrounds the steel tank and the subpile room. In addition, lead shields and bismuth windows are provided for special purposes, as required. The biological shield is poured monolithically on two sides and the top of the reflector tank, except for a movable concrete plug in the top shield. The thermal column end of the tank is shielded by a movable concrete door; the other end is shielded by stacked concrete blocks. The subfloor shielding consists of the dense-concrete wall which surrounds the subpile room and the concrete partition which shields the cooling system from the gas recombiner assembly.

REFLECTOR AND SHIELDING







INSTRUMENTATION

The instrumentation system consists principally of circuits which monitor reactor power and the performance of the gas-handling and cooling systems. In addition, there are instruments associated with other important variables, and there is provision for area radiation monitoring and similar instrumentations. The display and control parts of the system and most of its circuitry are housed in the control console.

Power level is measured by two types of sensing elements. In the range from the shutdown power level of about 0.1 milliwatt to 10 watts, two fission chambers are used. In the range from 0.1 watt to 50 kilowatts, two gamma-compensated ion chambers are used. Thus, the instrument ranges overlap to provide continuous measurements over the entire power range.

Temperature, pressure, and flow-measuring instruments for gas-handling and cooling system monitoring include instruments measuring sweep-gas flow, core temperature, catalyst bed temperature, recombiner gas pressure, hydrogen concentration, sweep-gas temperature, and surge-tank level.

The reactor is shut down automatically in the event the flux level or change in flux level exceeds preset values or if a malfunction occurs in the auxiliary equipment. The shutdown is accomplished by circuits which de-energize the magnets holding the control and safety rods, causing them to fall by gravity into the core.

When the shutdown occurs, instruments on the control console indicate to the operator the nature and location of the malfunction.

REACTOR FACILITIES

EXPERIMENTAL FACILITIES

The reactor has a variety of experimental facilities. Those listed below provide access to the nuclear activity of the reactor core:

1 horizontal beam tube, 4-inch diameter (6-inch hole in shield)
2 horizontal beam tubes, 4-inch diameter
4 vertical beam tubes, 4-inch diameter
2 horizontal beam tubes, 3-inch diameter
1 straight pneumatic tube, 2-inch diameter
1 curved pneumatic tube, 1½-inch diameter
1 central exposure tube, 1½-inch diameter
1 horizontal thermal column, 5 feet square
4 thermal column access ports, 6-inch diameter

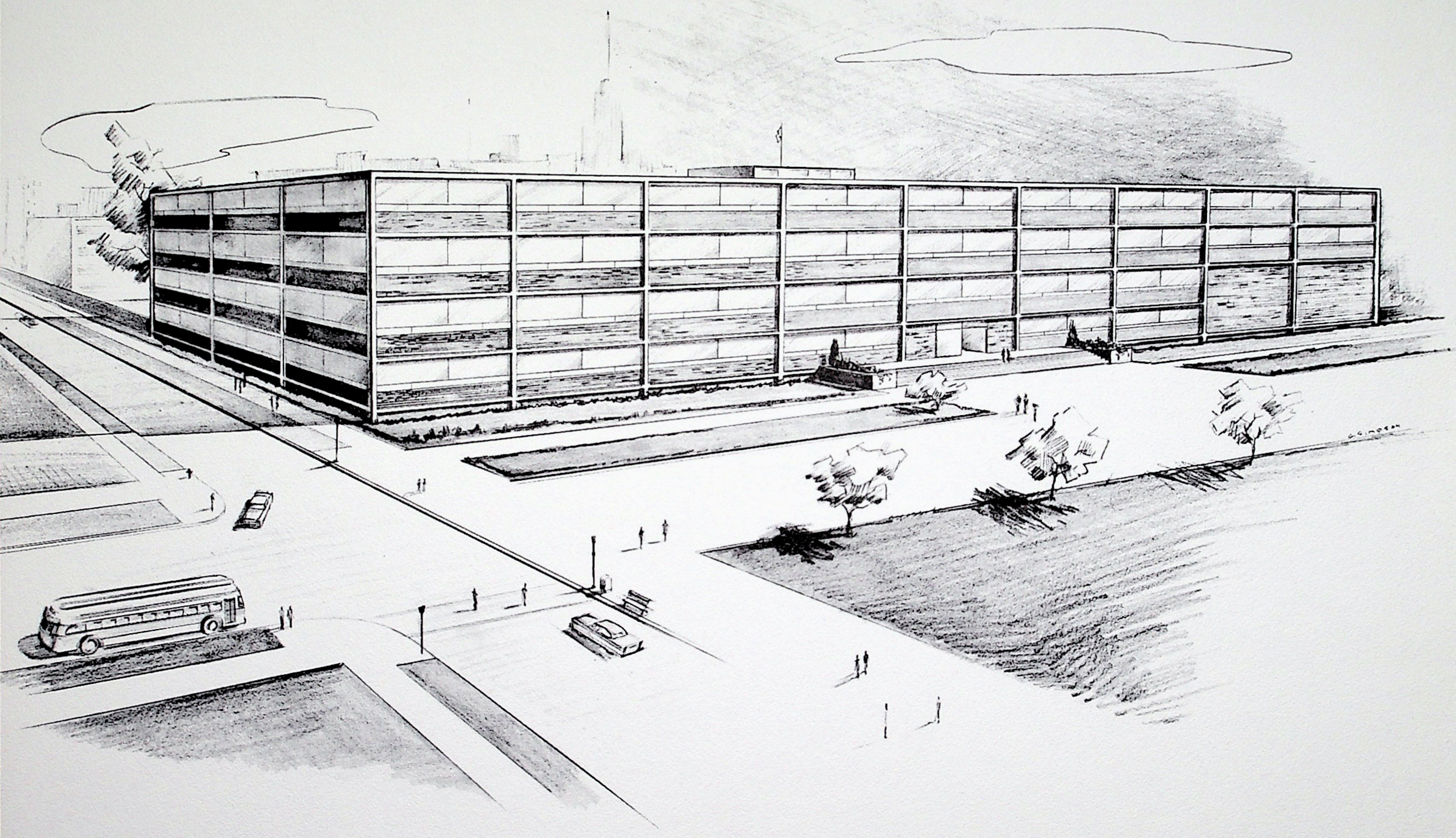
The tube facilities consist of steel sleeves extending through the concrete shield and aluminum thimbles or liners which reach to the immediate vicinity of the core. Each tube facility is equipped with a graphite reflector plug and a dense-concrete and steel shielding plug to be installed when the facility is not in use.

The horizontal thermal column is formed by a five-foot square column of graphite, in the center of which are nine removable graphite stringers. A large volume which may be used for exposures is provided between the end of the thermal column and the inner face of the rolling concrete door. The thermal column access ports open into this volume. The two square access ports are located in the thermal column shield door.

To take advantage of the gamma activity produced by the fission-product gases circulating through the gas recombiner tank, exposure facilities are provided which extend from the subpile room into the exposure room and into the valve room. The facilities listed below consist of steel sleeves and aluminum thimbles which extend through the dense concrete walls of the subpile room into the exposure room:

2 gamma ports, 4-inch diameter
2 gamma ports, 8-inch diameter
1 rectangular gamma slot, 6 by 18 inches

In addition, two 4-inch diameter gamma ports extend from the subpile room into the valve room. As with the beam tubes, each port is equipped with a plug to be installed for shielding purposes when the port is not in use.



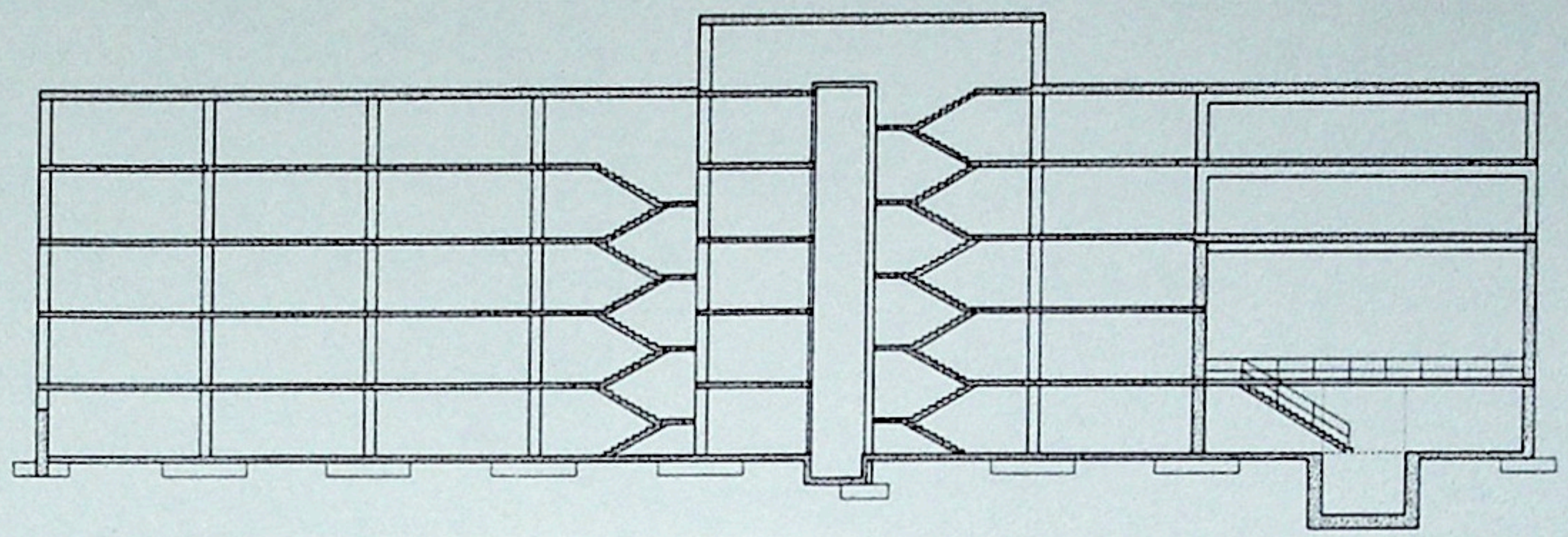
ARMOUR REACTOR BUILDING

The Armour research reactor is located in the new Physics and Electrical Engineering Research building, situated at the south end of the campus of the Illinois Institute of Technology near the intersection of 35th and State Streets in Chicago. Immediately adjacent to this building in the Technology Center area are other buildings which contain laboratories of the Armour Research Foundation.

The basement and the first and second floors at one end of the Physics and Electrical Engineering building are devoted to reactor operation and nuclear research. The reactor is installed in the west end of the building in a room which is three stories in height. Immediately adjacent to the reactor room is the area for nuclear and radiochemical research. The remainder of the first three floor levels is devoted to other areas of research in the Physics Department. The fourth and fifth floor levels will be occupied by the Electrical Engineering Research Department. The building is capped with a non-metallic penthouse to serve as an antenna laboratory.

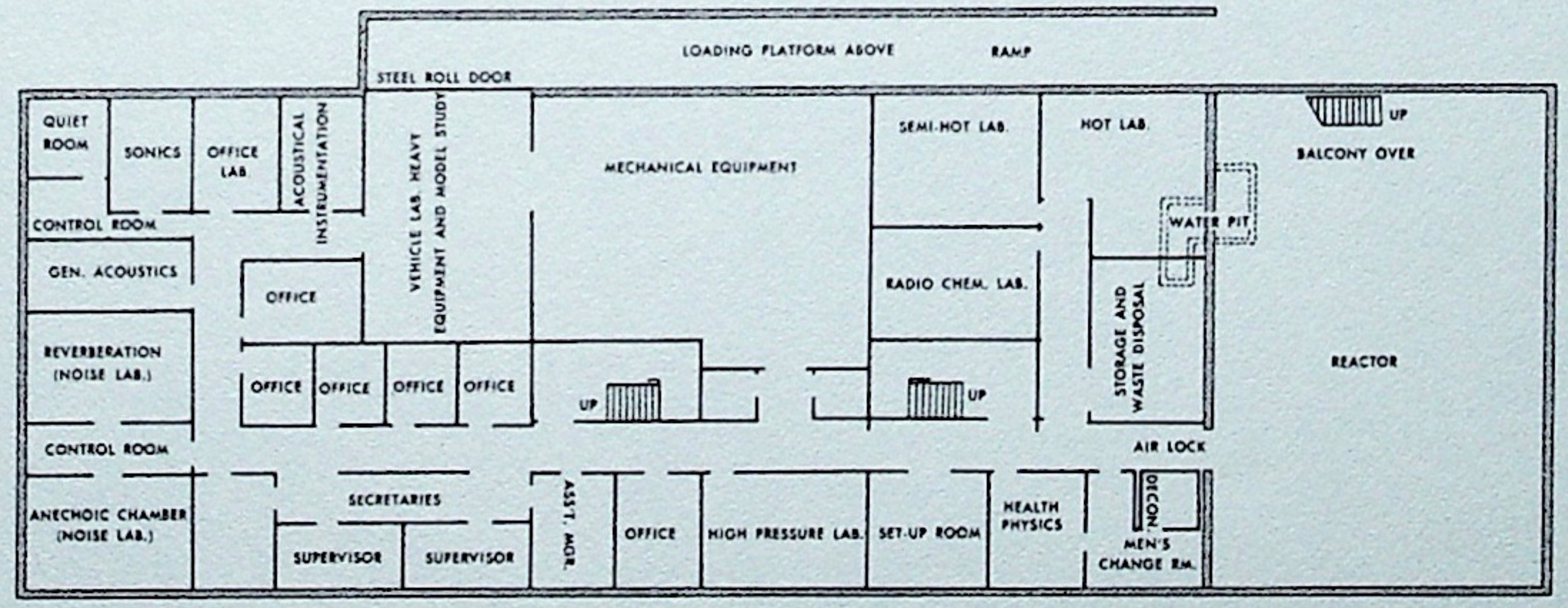
The reactor room is 72 feet long, 48 feet wide, and 30 feet high. The only permanent installation in the room is the reactor structure itself. The remaining floor area will be used for mobile experimental equipment. The concrete walls of the reactor room have been rendered impervious to gases and liquids by coating with a plastic resin. All room interior surfaces are suitably finished for easy decontaminability.

CROSS SECTION

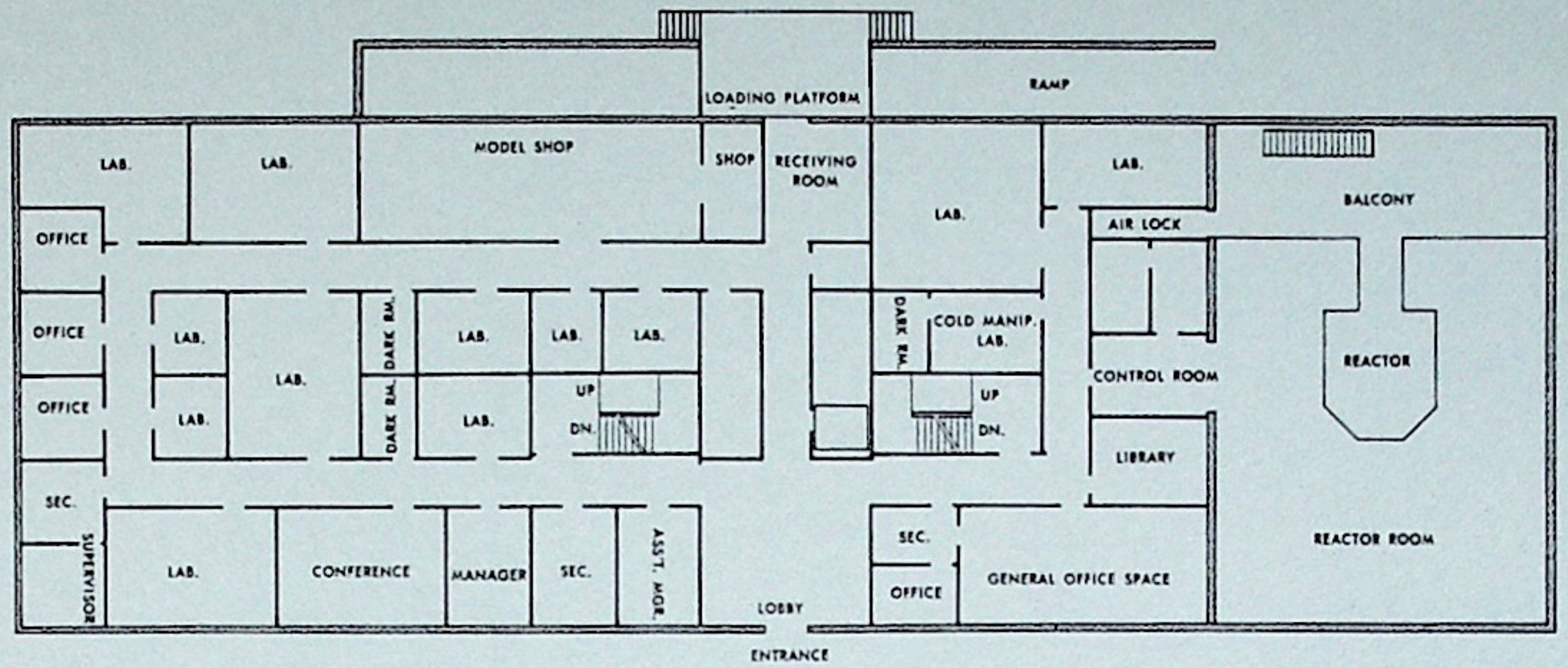


Access to the reactor room is gained through either of two air-locks. One of these is formed by a pair of 6-foot sliding doors and is at the floor level of the reactor room. The other air-lock has 42-inch doors and opens onto the balcony which communicates with the reactor top. Finally, access to the area below the reactor is made through a gas-tight door at the foot of the stairs. A second gas-tight door is used for access to the steel-lined subpile room itself. This latter door is interlocked with the scram system of the reactor. Doors forming an air-lock are interlocked so that the air-lock can never be left open.

BASEMENT

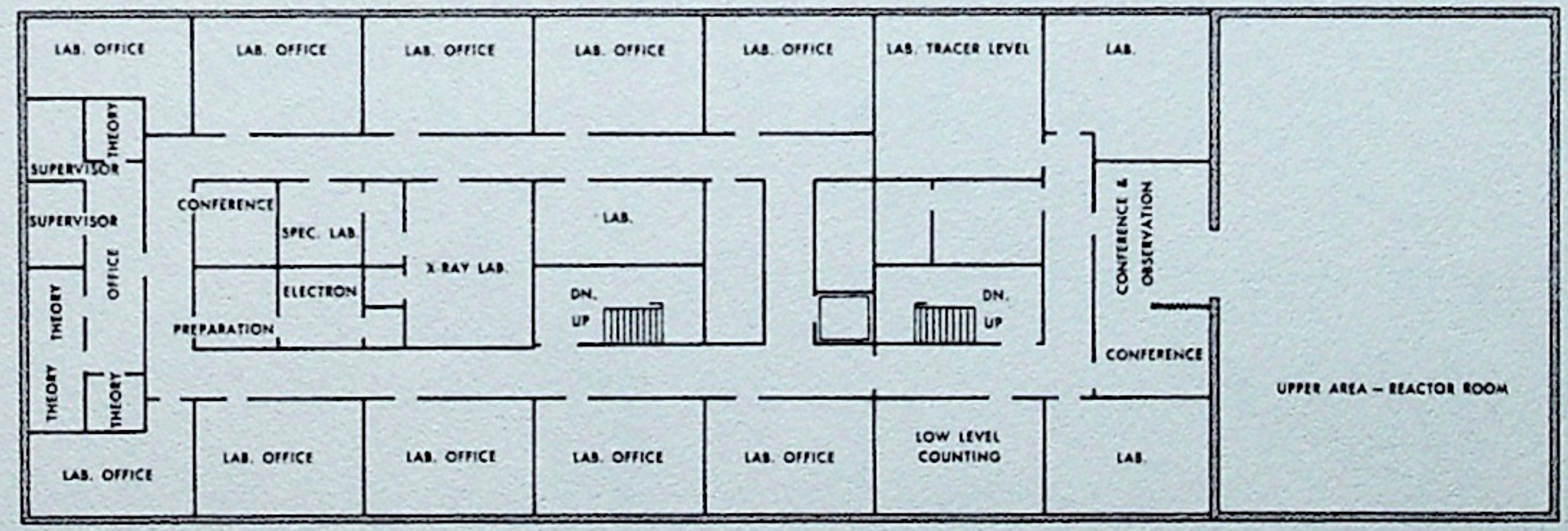


FIRST FLOOR



The entire building, of which the reactor facility is a part, is air conditioned. Both the reactor room and the radiochemical areas have their own ventilating systems independent from the rest of the building. To ensure positive control of the flow of air, the forced-air ventilation system is arranged to maintain the radiochemical laboratories at a negative pressure with respect to the rest of the building, and the reactor room at a negative pressure relative to the radiochemical laboratories. This arrangement provides that all unfiltered air flow will be into the source of potential contamination rather than out of it.

SECOND FLOOR

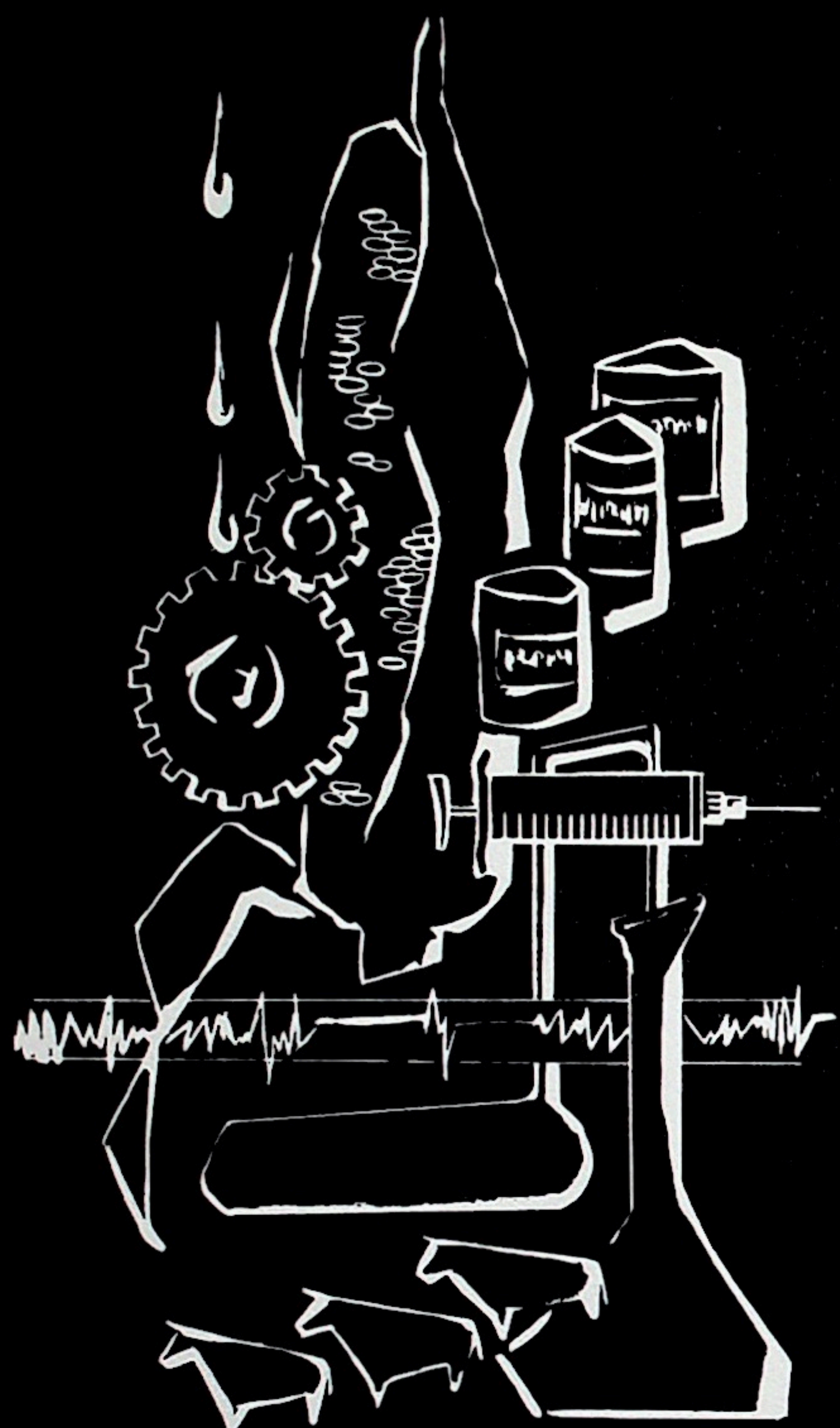


ADMINISTRATION AND USE OF REACTOR FACILITY

Construction costs for the reactor facility were borne jointly by Armour Research Foundation, which serves as owner, operator, and administrator, and by twenty-five private industrial organizations, which are referred to as participators. These participating companies are entitled to priority use of the reactor without equipment charge. In addition, an extensive research program will be conducted by the Foundation for these companies to establish feasibility of atomic techniques in the various areas of interests of the companies. Finally, the participators may consult freely with the staff on all problems relating to atomic technology and receive assistance in the use of these techniques in their own laboratories.

To the participating organizations and to all private industry in the area, the Armour research reactor offers a wide and extremely promising field of nuclear research.

PRESENT EXPERIENCE



The following abbreviated list contains illustrative examples of areas where radioactivity and radiation have been successful. In nearly every case, work previously has been limited to radioisotopes obtainable from the AEC, since a reactor immediately at hand has not been available for such research.

Agriculture and Biochemistry

- Phosphate fertilizer studies in plants
- Study of exchange reactions in soil

Heavy Chemicals

- Solubility of various materials in organic solvents
- Pilot plant experiments with labeled organic compounds
- Mechanism of the Fischer-Tropsch reaction
- Study of transfer of materials in turbulent air streams

Ceramics, Concrete, Building Materials, and Glass

- Detection of microscopic fractures in concrete of various compositions
- Studies of reactions of alkalies and sulphates in cement

Electricity and Electronics

- Study of material transfer and erosion in electrical contacts
- Study of temperature stability of semiconductors

Food

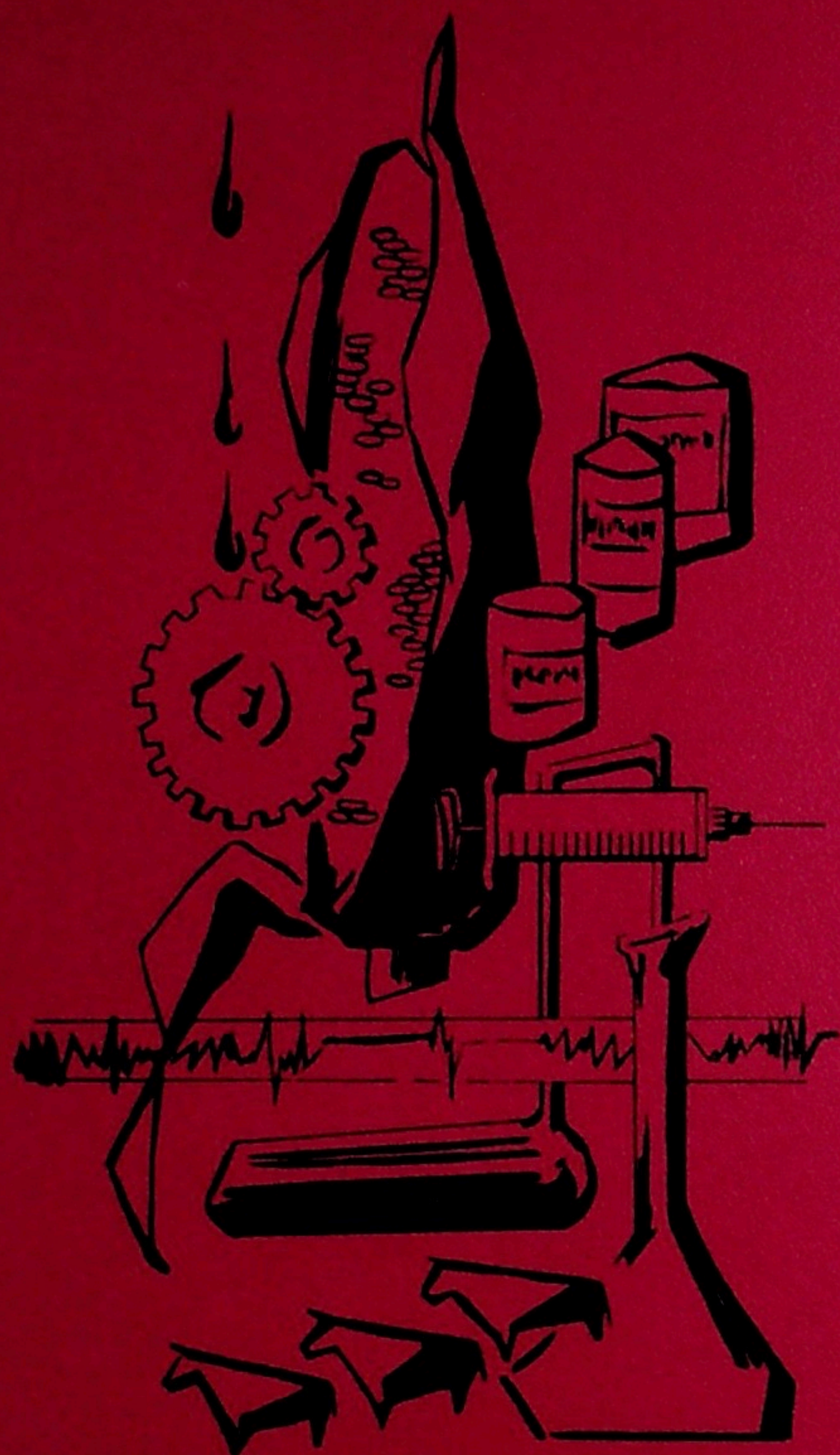
- Study of food deterioration using labeled glucose
- Determination of formaldehyde content in eggs and insulin

Machinery

- Gear wear under lubrication
- Study of efficiency of food mixers

Metallurgy

- Effect of high temperatures and pressures on hydrogen diffusion in metals
- Mechanism of surface treatment of metals
- Study of kinetics of slag-metal reactions involving sulfur



Oil and Gases

Study of high temperature catalytic reactions

Oil consumption in engines

Mechanism of gasification reactions for coal

Plastics

Studies on polymerization in long chain plastics

Rubber and Leather

Mechanics of polymerization and vulcanization

Measurement of tread wear

Soap

Effect of phosphates on surface active agents

Study of the mechanics of detergents

Textiles

Study of dye processes with labeled metalized dyes

FUTURE POSSIBILITIES

Sterilization, Pasteurization, and Infestation Studies on Foods and Drugs

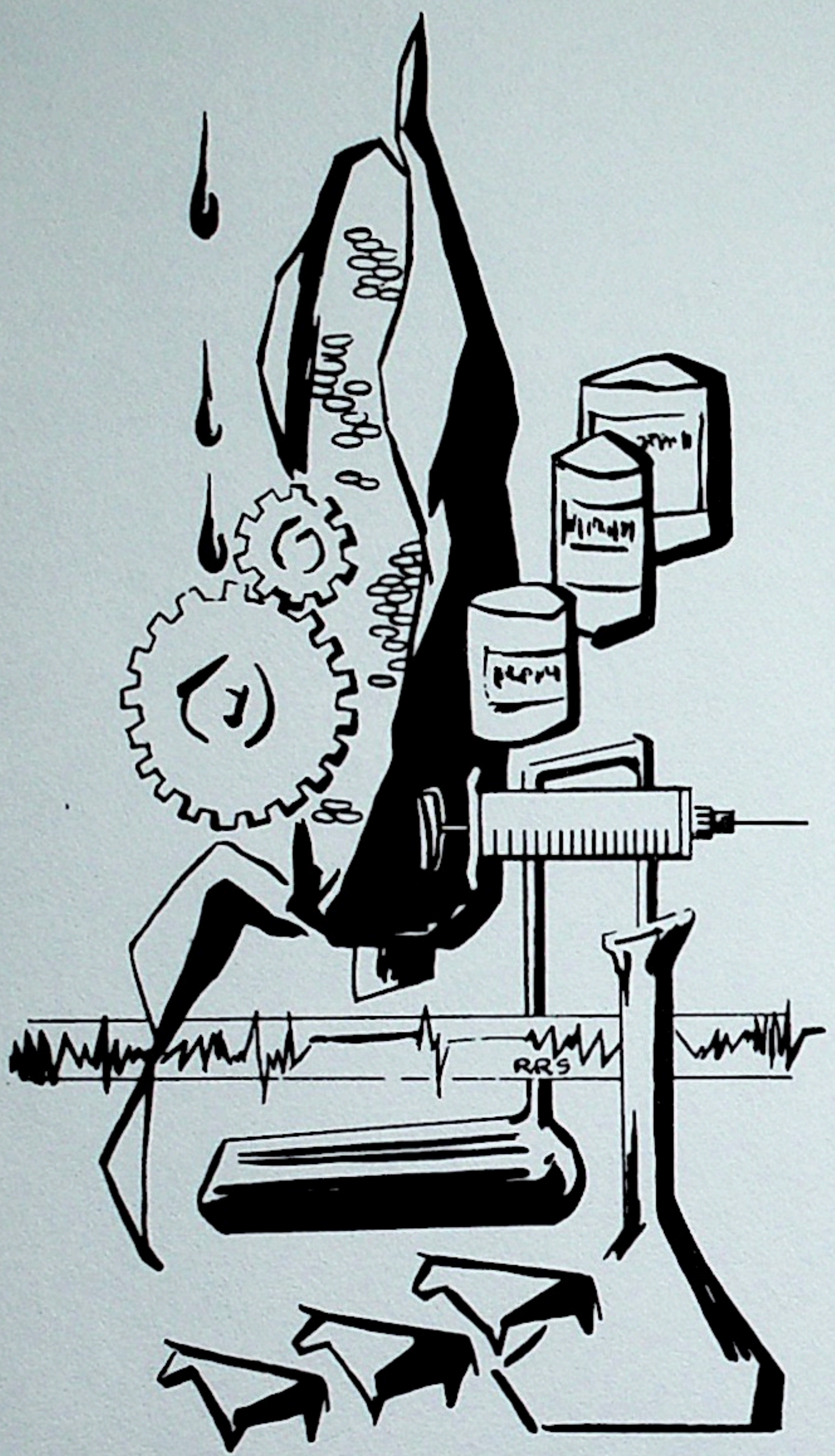
The impact of successful developments in this field on the food, drug, and packaging industry would be considerable.

High Polymer Studies

The mechanism of catalysis can be examined with short-lived tracers, and radiation effects on catalytic agents may prove beneficial.

Catalysis

The structure of plastics, rubber, and similar materials can be examined and radiation treatments can produce new properties.



Structure and Properties of Glass and Ceramics

Neutron diffraction and neutron bombardment can be used to learn more about the not-understood structure of glass. This could clear the way to development of materials with improved properties.

Development and Studies of Metals and Alloys

Since many tracer techniques are applicable to diffusion and structure problems, radiation damage effects can be studied.

Wear and Friction Studies

Design of mechanisms con be facilitated by the ability to determine wear properties; studies on the nature of friction could lead to new lubrication developments.

Radiation Effect in Chemistry

It is now known that many chemical reactions will occur in the presence of high energy radiation which would not occur under ordinary circumstances. The reactor will permit development of new chemical processes and products using neutron and gamma-ray bombardment.

Peripheral Studies in Power Reactors

The future importance of nuclear power reactors is evident. The facility will permit design studies—such as exponential experiments and flux maps—as well as instrumentation and corrosion studies.

Structural Problems in Organic and Inorganic Chemistry

Many problems of crystal structure and hydrogen location in solid state chemistry can be attacked by neutron diffraction. Such studies may lead not only to better understanding, but also to new materials and processes.

Medical Applications

Literally hundreds of diagnostic and therapeutic techniques in modern medicine depend upon radioisotopes.

Trace Element Determinations

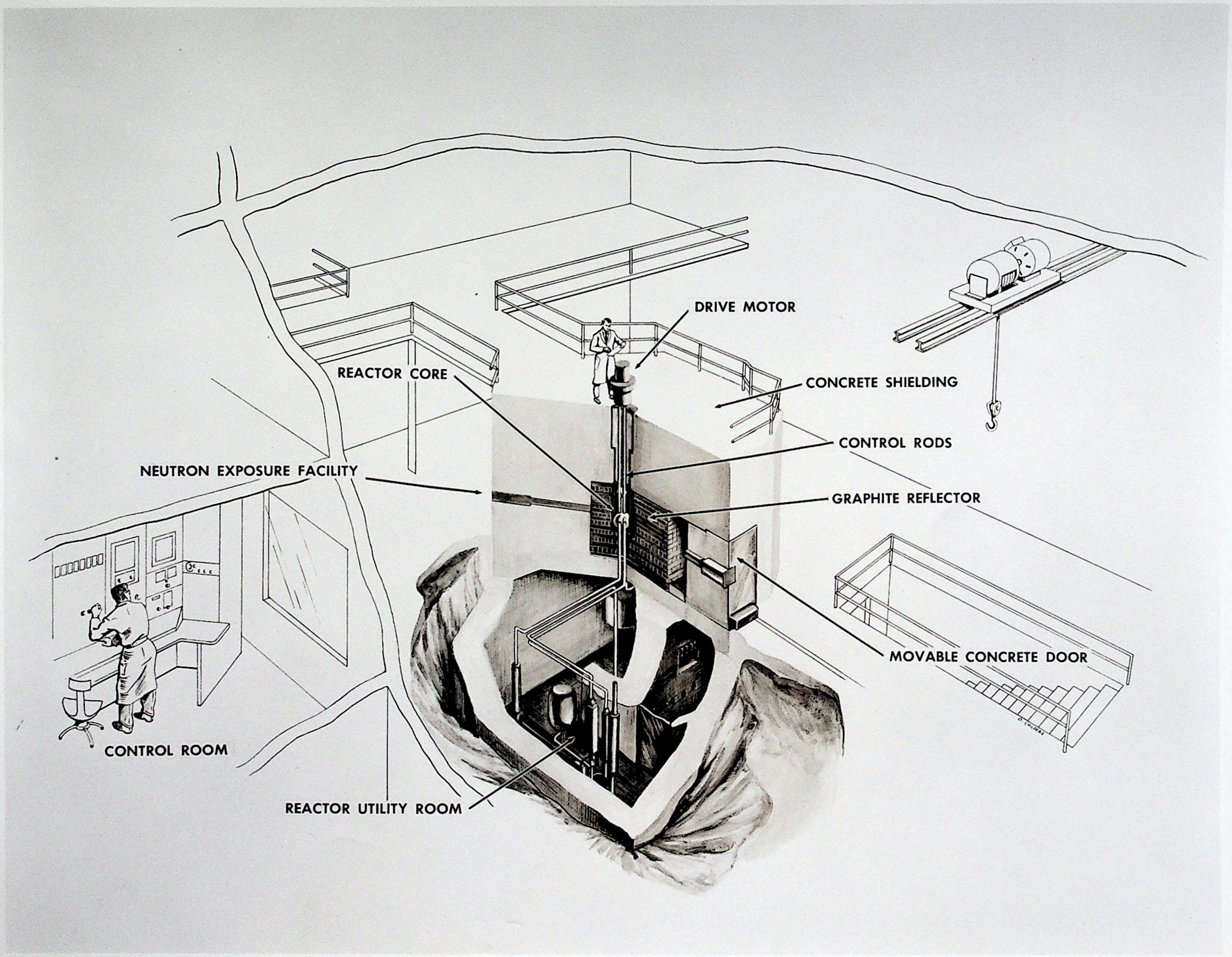
Methods are known of measuring trace element concentrations at levels of magnitude below those accessible to ordinary analysis.

Transistor and Semiconductor Studies

Development of new materials, and the improvement of presently-known ones by irradiation, activation, and tracer techniques can be instigated.

CONCLUSION

The Armour research reactor, as conceived by Atomics International, a division of North American Aviation, Inc., brings to industry a completely new and versatile tool for industrial research. Under the administration of the Foundation's large staff, which represents talent in virtually every technical area of industrial concern, and with the enthusiastic support of private business, the Armour research reactor heralds the beginning of the new Age of Industry.


DRIVE MOTOR
REACTOR CORE
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CONTROL RODS
NEUTRON EXPOSURE FACILITY
GRAPHITE REFLECTOR
MOVABLE CONCRETE DOOR
CONTROL ROOM
REACTOR UTILITY ROOM

North American Aviation, Inc.
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIFORNIA

PRESS RELEASE

FOR RELEASE AS NOTED

N-31

CHICAGO, ILL.--Operation of the first nuclear reactor built for private industrial research began here today. The 50,000 watt research reactor, designed and built by Atomics International, a division of North American Aviation, Inc., for the Armour Research Foundation, is intended solely for peacetime use by industry.

Located on the campus of the Illinois Institute of Technology, the reactor opens an entirely new field in industrial research and development by providing an on-the-spot source of high-energy gamma rays and neutrons. Short-lived radioisotopes, useful in medical, industrial and scientific research, will be available locally from the reactor. It will not be used to generate electrical power.

The "solution type" reactor uses as "fuel" enriched uranium dissolved in about four gallons of water. Atomic fission, the "splitting" of atoms which produces radioactivity and neutrons, takes place in the reactor core, a steel sphere about one foot in diameter.

The reactor core is surrounded by an 8 x 5 x 5 foot stack of graphite bars which act as a reflector. Dense concrete, five feet thick, forms the exterior shield.

Rate of fission in the reactor is controlled by four boron rods. When placed near the reactor core the rods absorb neutrons, thus stopping the fission process. When the rods are withdrawn fission begins again.

(more)

A particular feature of the reactor is its "self contained" design which confines all the radioactivity within the shield. No gaseous or liquid materials are exhausted or discharged.

The reactor will be used in many fields including biology, petroleum technology, metallurgy, electronics, textiles and chemistry. Of particular interest are studies in the atomic radiation of foods to extend the length of time they can be kept edible. Among the processes offering promise are the pasteurization of fresh meat to extend its shelf life, "cold" sterilization of meats and vegetables for indefinite storage, deinfestation of grains and flour and prevention of sprouting in potatoes and onions.

Radioisotopes provide some of the most useful and promising applications of the reactor. Such "short-lived" isotopes have not been widely used because of the time delay and resultant radioactivity loss if moved over long distances.

Because radioisotopes send out "signals" that can be detected and measured, a small quantity of material can be radioactively "tagged" and its invisible course traced in metals, plants and animals. Flaws in the casting and welding of metals can be easily detected in this manner. Used as tracers that can be picked up by detecting instruments, radioisotopes are revealing the secrets of how plants grow and the most efficient ways they can be fertilized and irrigated.

In addition to the reactor for the Armour Research Foundation, Atomics International has contracted to build a research reactor for the Atomic Energy Research Institute of Japan and a medical reactor for the University of California at Los Angeles Medical Center.

(more)

In the nuclear power field, Atomics International has designed and is building a sodium graphite power reactor which will go into operation in California the latter part of this year. This is the SRE, or Sodium Reactor Experiment, a nuclear power reactor being built for the Atomic Energy Commission as part of the Commission's program to develop economical power from atomic energy.

Two solution-type reactors, built by Atomics International for the AEC for nuclear research work, have been in operation in California for several years. One is operating at Atomics International's facility in Los Angeles and the other at the Livermore Research Laboratory.

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Technicians (left) check a shielding plug in one of the experimental ports of the world's first private nuclear reactor for industrial research, constructed at Armour Research Foundation of Illinois Institute of Technology, Chicago. The reactor was designed and built by Atomics International, a division of North American Aviation, Inc. Scientist at right inspects the mechanism that closes and opens the 40,000 pound door of the reactor.

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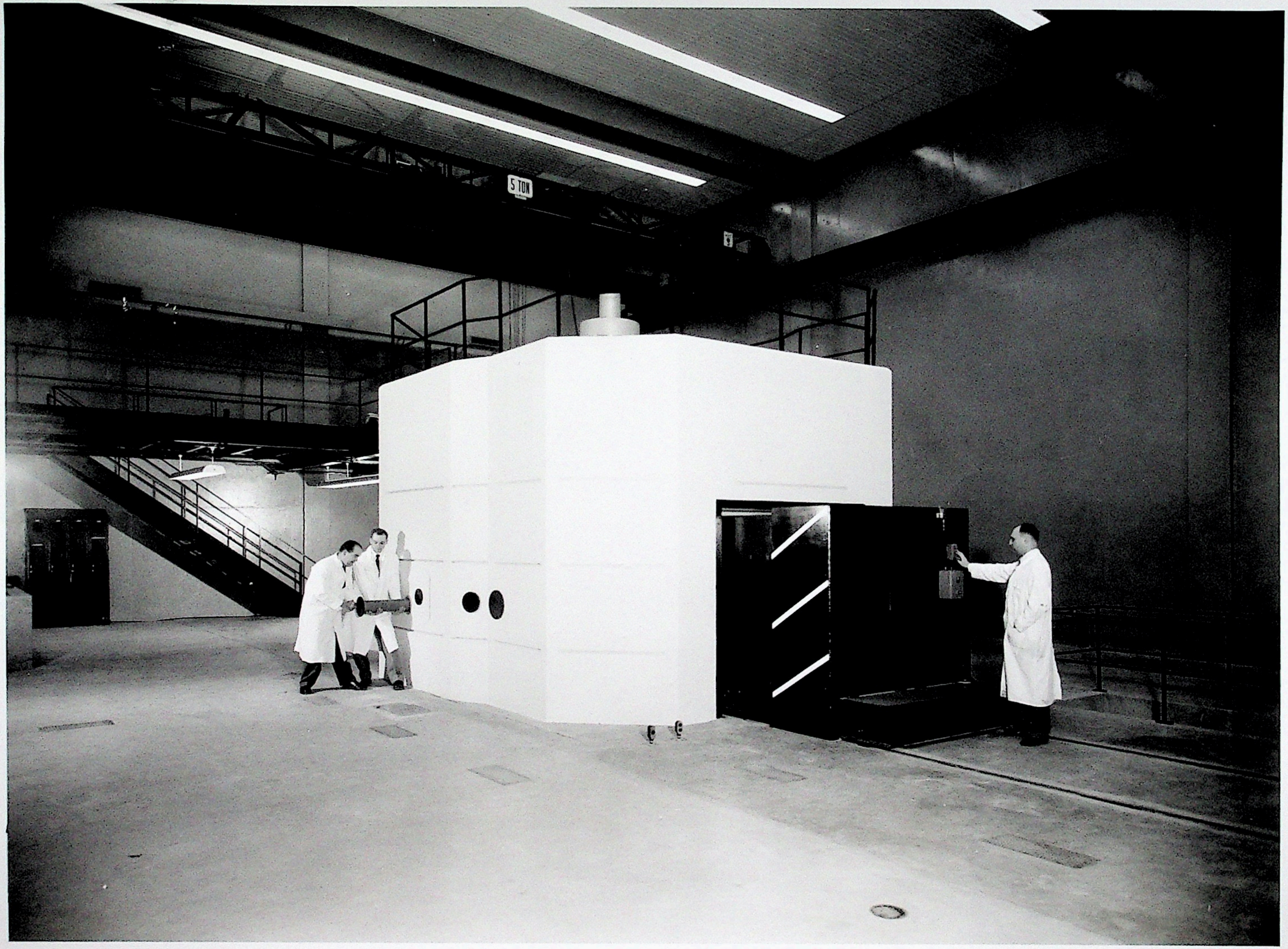
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North American Aviation, Inc.
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PRESS RELEASE

THE 50 KILOWATT SOLUTION TYPE INDUSTRIAL RESEARCH REACTOR

Designed and built by Atomics International, a division of North American Aviation, Inc., for the Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois.

REACTOR DESCRIPTION AND OPERATION

The Armour Research Foundation reactor is a homogeneous solution-type reactor, designed to operate at 50 kilowatts and to produce a maximum thermal neutron flux of about 1.7×10^{12} neutrons/cm^2-sec at the center of the reactor core. The reactor consists of a core assembly, gas-handling, fuel-handling, and cooling systems, a control- and safety-rod system, and a reflector assembly, together with the necessary instrumentation and shielding for safe and efficient operation. In addition, exposure facilities are provided through which the neutron flux and gamma-ray radiation are available in various intensities for experimental purposes.

The core assembly contains the fuel, which serves as the primary power source, and the moderator, which controls the neutron speed. The fuel consists of enriched uranium, in the form of uranyl sulphate, dissolved in ordinary water, which serves as the moderator. The core assembly includes a spherical stainless-steel tank containing four control-rod thimbles which project vertically into the tank, central exposure tubes which extend horizontally through the center of the tank, cooling coils, a line for filling and draining fuel solution, and a gas outlet tube leading to the solution overflow tank and the gas-handling system.

The gas-handling system controls and processes the gaseous products generated within the fuel solution contained in the core tank. The system consists essentially of the recombiner assembly, which is

located below the reactor in the subpile room, which is below the reactor, and piping connecting the recombiner to the core tank. The principle functions of this system are (1) to recombine the hydrogen and oxygen which are produced by radiolysis of the solution water and return the resulting water to the core tank, and (2) to confine the radioactive fission-product gases and provide for their disposal, when necessary.

The fuel-handling system provides a means of filling and draining the core tank. The system consists of a safe-geometry storage tank located in the subpile room, and the piping and valving connecting the tank to the reactor core and to the external servicing connections. The tank, which is shielded by lead bricks, is designed for complete subcriticality, even when it contains all of the core solution.

The cooling system maintains all significant reactor temperatures at their proper values. The system includes a primary coolant pump, the main and recombiner heat exchangers, core cooling coils, and the necessary piping and valving. Heat energy is removed from the core and recombiner by the primary coolant, which is distilled water. The heat energy is then transferred in the main heat exchanger to the secondary coolant, which is ordinary city water. The secondary coolant is completely isolated from the primary coolant water, and hence from any radioactivity; however, it is continuously monitored so that a malfunction in the cooling system will automatically close it off from the city water and sewage system.

The control and safety rod system consists of four boron carbide cylinders and the appropriate control mechanisms and circuitry to position the cylinders within the reactor core. These cylinders, or rods, absorb neutrons and thus control the intensity of the fission reaction. One of the four rods is driven by a servo-controlled motor

and functions as the automatic regulating rod. Each control rod is held to its drive mechanism by an electromagnet located at the bottom of the drive mechanism. When it is desired to "scram" the reactor - that is, to shut it down quickly - the electromagnets are de-energized, thus permitting the rods to fall freely by gravity into the control-rod thimbles extending within the core tank.

The reflector assembly increases the efficiency of reactor operation by confining neutron activity to the reactor core. The reflector consists of rectangular graphite blocks which are stacked in layers around the core assembly. These blocks form a rectangular prism about 6-1/2 feet by 5 feet by 5 feet which is enclosed in a steel shielding tank.

Shielding for the reactor is provided by a five-foot thick biological shield of dense hematite-colmanite concrete which surrounds the reflector and the subpile room. In addition, lead shields and bismuth windows are provided for special shielding purposes, as required. The concrete shielding is sufficient to reduce radiation levels at the outer surface to less than one tenth of the generally accepted safe dosage rate specified for laboratories handling radioactivity.

The instrumentation system consists principally of circuits which monitor reactor power and the performance of the gas-handling and cooling system. In addition, there are instruments associated with other important variables, and there is provision for area radiation monitoring and similar instrumentation.

Power level is measured by fission chambers and gamma-compensated ion chambers. Temperature-, pressure-, and flow-measuring instruments for gas-handling and cooling system monitoring include instruments measuring sweep-gas flow, core temperature, catalyst-bed temperature, recombiner gas pressure, hydrogen concentration, sweep-gas

temperature, and surge-tank level.

The reactor is shut down automatically in the event the flux level or change in flux level exceeds present values, if a malfunction occurs in the auxiliary equipment, or in the event of a power failure. The shutdown is accomplished by circuits which de-energize the magnets which hold the control and safety rods, causing them to fall by gravity into the core. When shutdown occurs, instruments on the control console indicate to the operator the nature and location of the malfunction.

EXPERIMENTAL FACILITIES

The reactor is located in the new Physics and Electrical Engineering Research Building, which is located at the south end of the Technology Center in Chicago. The reactor is installed in the west end of the building, in a room which is 72 feet long, 48 feet wide, and 30 feet high. The remainder of the building comprises nuclear laboratories and other areas associated with reactor operation.

The reactor has a variety of experimental facilities. Those listed below provide access to the nuclear activity of the reactor core.

1 horizontal beam tube, 4-inch diameter (6-inch hole in shield)
2 horizontal beam tubes, 4-inch diameter
4 vertical beam tubes, 4-inch diameter
2 horizontal beam tubes, 3-inch diameter
1 straight pneumatic tube, 2-inch diameter
1 curved pneumatic tube, 2-inch diameter
1 central exposure tube, 1-1/2 inch diameter
1 horizontal thermal column, 5-feet square
4 thermal column access ports, 6-inch diameter

The tube facilities consist of steel sleeves extending through the concrete shield and aluminum thimbles or liners which reach to the immediate vicinity of the core. Each tube facility is equipped with a graphite reflector plug and a dense concrete and steel shielding plug to be installed when the facility is not in use.

The horizontal thermal column is formed by a five-foot square column of graphite, in the center of which are nine removable graphite stringers. A large volume which may be used for exposures is provided between the end of the thermal column and the inner face of a moveable concrete door. The thermal column access ports open into this volume.

To take advantage of the gamma activity produced by the fission-product gases circulating through the gas recombiner tank, exposure facilities are provided which extend from the subpile room into the exposure room and into the valve room. The facilities listed below consist of steel sleeves and aluminum thimbles which extend through the dense concrete walls of the subpile room into the exposure room.

2 gamma ports, 4-inch diameter

2 gamma ports, 8-inch diameter

1 rectangular gamma slot, 6 inches by 18 inches

In addition, two 4-inch diameter gamma ports extend from the subpile room into the valve room. As with the beam tubes, each port is equipped with a plug to be installed for shielding purposes when the port is not in use.

USE OF THE REACTOR FACILITY

The Armour Research Foundation reactor offers a wide and extremely promising field of nuclear research. Capable of operating at a power level of 50,000 watts, the reactor will produce neutrons and gamma radiation for research and development in the fields of biology, metallurgy, food processing, electronics, chemistry, textiles,

oils and gases, rubber and leather, machinery, building materials, and allied industrial and scientific pursuits. In addition, short-lived radioisotopes, useful in medical, industrial, and scientific research but hitherto unavailable because of the time delay in transit, will be available locally from the installation.

As an example of the new and powerful techniques made possible by the reactor, "neutron activation" now permits what is probably the most sensitive method of chemical analysis known to date. For many elements, a sensitivity of detection of one-trillionth of a gram can be achieved.

Another newly-developed technique is that of "neutron diffraction." Since the diffraction of neutrons is almost independent of atomic number, there is now available a powerful method of structure analysis which complements, and frequently exceeds, the standard x-ray diffraction techniques. This technique has already proved valuable in the study of organic compounds, hydrogen and oxygen in solids, and anti-ferromagnetic materials.

Bombardment of materials by radiation produces effects in almost infinite variety - usually deleterious, but occasionally beneficial. The study of such effects in glasses, plastics, organic systems, and metallic alloys can be undertaken readily with the reactor. The flux also will permit study of the influence of radiation on chemical reactions, some of which are known to accelerate under these conditions.

SPECIFICATIONS FOR
ARMOUR RESEARCH FOUNDATION REACTOR

I. REACTOR OPERATING CHARACTERISTICS

Design Power	50 kw
Zero power critical mass*	850 Gm U^{235}
Maximum thermal neutron flux	1.7×10^{12} n/cm^2-sec
Mass coefficient of reactivity*	0.031%/gm
Temperature coefficient of reactivity*	-0.029%/°C
Power coefficient of reactivity*	-0.006%/kw
Fuel solution temperature at 50 kw*	80°C
Excess reactivity at 20°C, zero power*	3%
Reactivity held in control and safety rods*	8% (2% each rod)
$H:U^{235}$ Atomic ratio*	350
U^{235} concentration*	75 gm/liter
Power density, maximum	5.5 watt/cm^3
Power density, average	3.85 watt/cm^3

II. CORE ASSEMBLY

Outside diameter of core tank	12.5 in.
Construction of core tank	Stainless steel sphere
Volume of overflow tank	2 liters

III. GAS-HANDLING SYSTEM

Type of system	Closed
Atmosphere	Oxygen
Operating pressure	Slightly below atmospheric
Test pressure	300 psig
Gas circulation	Water-operated ejector nozzle
Rate of gas flow	8cfm
Water circulation	Canned rotor pump
Rate of water flow	25 gpm
Total volume of system	30 liters
Recombiner assembly	
Type of catalyst	Platinum (0.3% by weight platinum deposited on 1/8-inch cylindrical pellets of aluminum oxide)
Bed temperature	100° - 150° C
Total water volume	10 - 15 liters
Water temperature	Less than 50° C

*Approximate values

IV. FUEL-HANDLING SYSTEM

Type of system	Non-circulating
Drain-and-fill tank	
Construction	Stainless steel
Geometry	Sub-critical
Volume	5 gallons

V. COOLING SYSTEM

Type of system	
Primary	Closed, pump operated
Secondary	Open, city pressure operated
Core heat exchanger	
Construction of cooling coils	10 loops of 1/4-inch stainless steel tubing connected in parallel
Inlet temperature	80° F
Outlet temperature	110° F
Rate of flow	12 gpm
Recombiner heat exchanger	
Inlet temperature	80° F
Outlet temperature	95° F
Rate of flow	2 gpm
Main heat exchanger	
Inlet temperature (primary coolant)	109° F
Outlet temperature (primary coolant)	80° F
Rate of flow (primary coolant)	14 gpm
Inlet temperature (secondary coolant)	70° F
Outlet temperature (secondary coolant)	89° F
Primary coolant pump	
Type	Constant-speed centrifugal pump
Rating	14 gpm at 50 psig
Primary Coolant	Distilled water
Secondary coolant	City water
Surge tank	
Volume	5 gallons
Test pressure	100 psig

VI. CONTROL ROD SYSTEM

Control rods	
Composition	Boron carbide
Construction	Cylindrical, 5/8 inch in diameter by 16 inches in length, enclosed in stainless steel
Number of rods	Four
Rod travel	12 inches
Rod withdrawal rate	0.1 inch/sec
Drive mechanism	Rack and pinion type, actuated through a gear reduction mechanism by an electric motor.
"Scram" operation	
Type	Gravity
Free fall travel	10 inches
Air-cushioned travel	2 inches

VII. REFLECTOR

Construction	15 layers of graphite blocks, arranged in a rectangular prism
Size	6-1/2 feet by 5 feet by 5 feet
Composition of blocks	AGOT-grade graphite, with density of 1.67 gm/cm^3 and boron content of less than 0.1 ppm

VIII. BIOLOGICAL SHIELD

Construction	Dense concrete, monolithically poured
Composition	Hematite ore, mill scale, colmanite, portland cement, and water
Density	3.5 gm/cm^3

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Cooling system of the Armour Research Foundation reactor built by Atomics International, a division of North American Aviation, Inc. This system maintains all significant reactor temperatures at specified levels. Primary coolant pump, below, circulates distilled water through the core cooling coils and recombiner heat exchanger and thence to the main heat exchanger (long tank below center), where heat generated in the reactor is transferred to the secondary coolant. Rate of flow through the recombiner heat exchanger and cooling coils is measured by two flowmeters shown in left center. Located just to the right of the larger flowmeter is a surge tank, which is provided to smooth out pressure variations in the primary cooling system.

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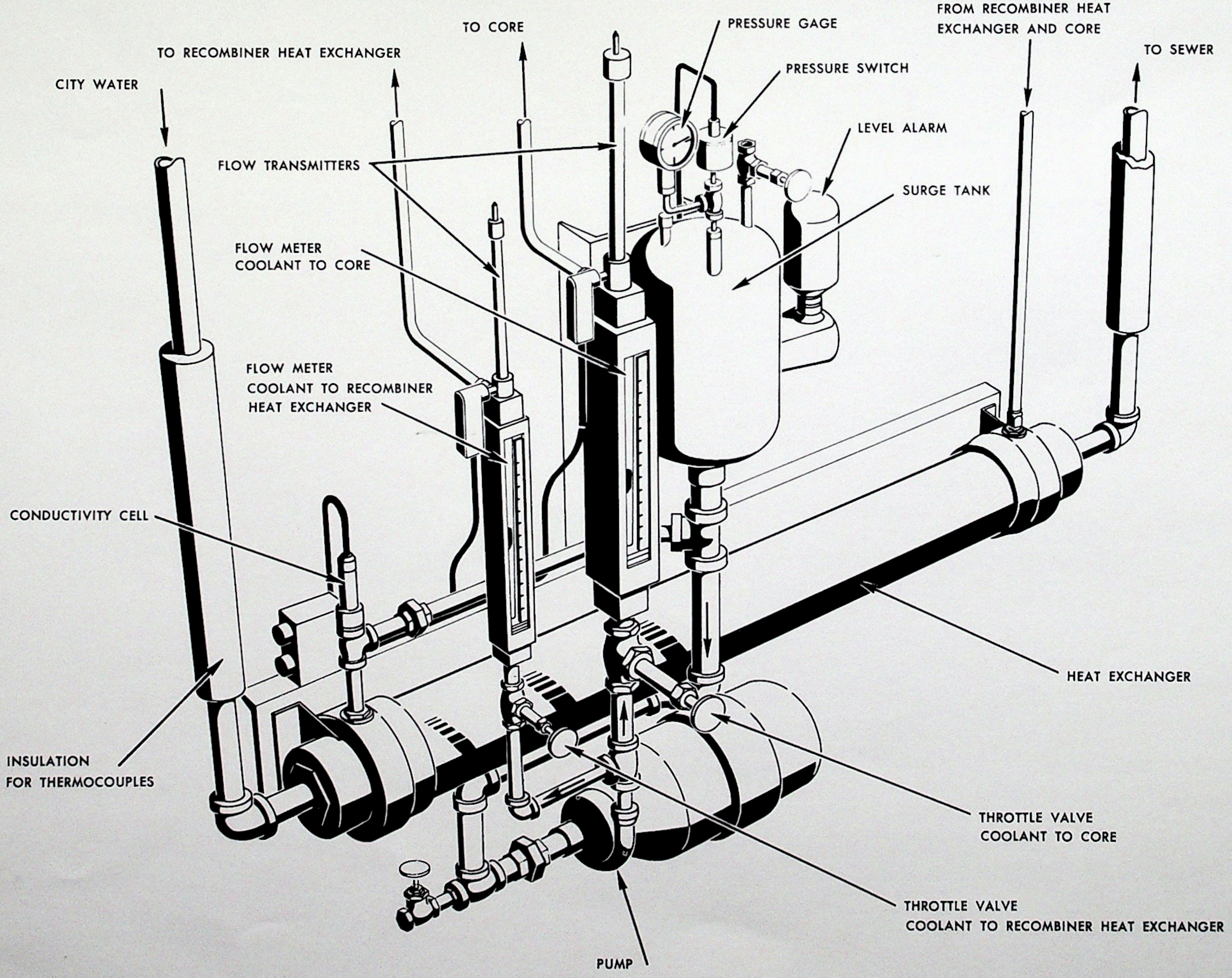
TO CORE
PRESSURE GAGE
FROM RECOMBINER HEAT
EXCHANGER AND CORE
TO RECOMBINER HEAT EXCHANGER
TO SEWER
PRESSURE SWITCH
CITY WATER
LEVEL ALARM
FLOW TRANSMITTERS
SURGE TANK
FLOW METER
COOLANT TO CORE
FLOW METER
COOLANT TO RECOMBINER
HEAT EXCHANGER
CONDUCTIVITY CELL
HEAT EXCHANGER
INSULATION
FOR THERMOCOUPLES
THROTTLE VALVE
COOLANT TO CORE
THROTTLE VALVE
COOLANT TO RECOMBINER HEAT EXCHANGER
PUMP

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Sectional views of Armour Research Foundation reactor, built by Atomics International, a division of North American Aviation, Inc., showing general arrangement of major components. Plan view, above, shows beam tubes and thermal column extending outward from reactor core through the dense concrete biological shield. These facilities provide controlled access to neutrons and gamma rays produced in the core. Vertical view, below, shows core tank, in center, imbedded in reflector, which is composed of graphite blocks. Control and safety rod system extends upward from core into reactor room, and piping leads downward from core into subpile room, which contains the fuel-handling, gas-handling, and cooling systems (not shown). Entire structure is enclosed in a thick shield of dense concrete.

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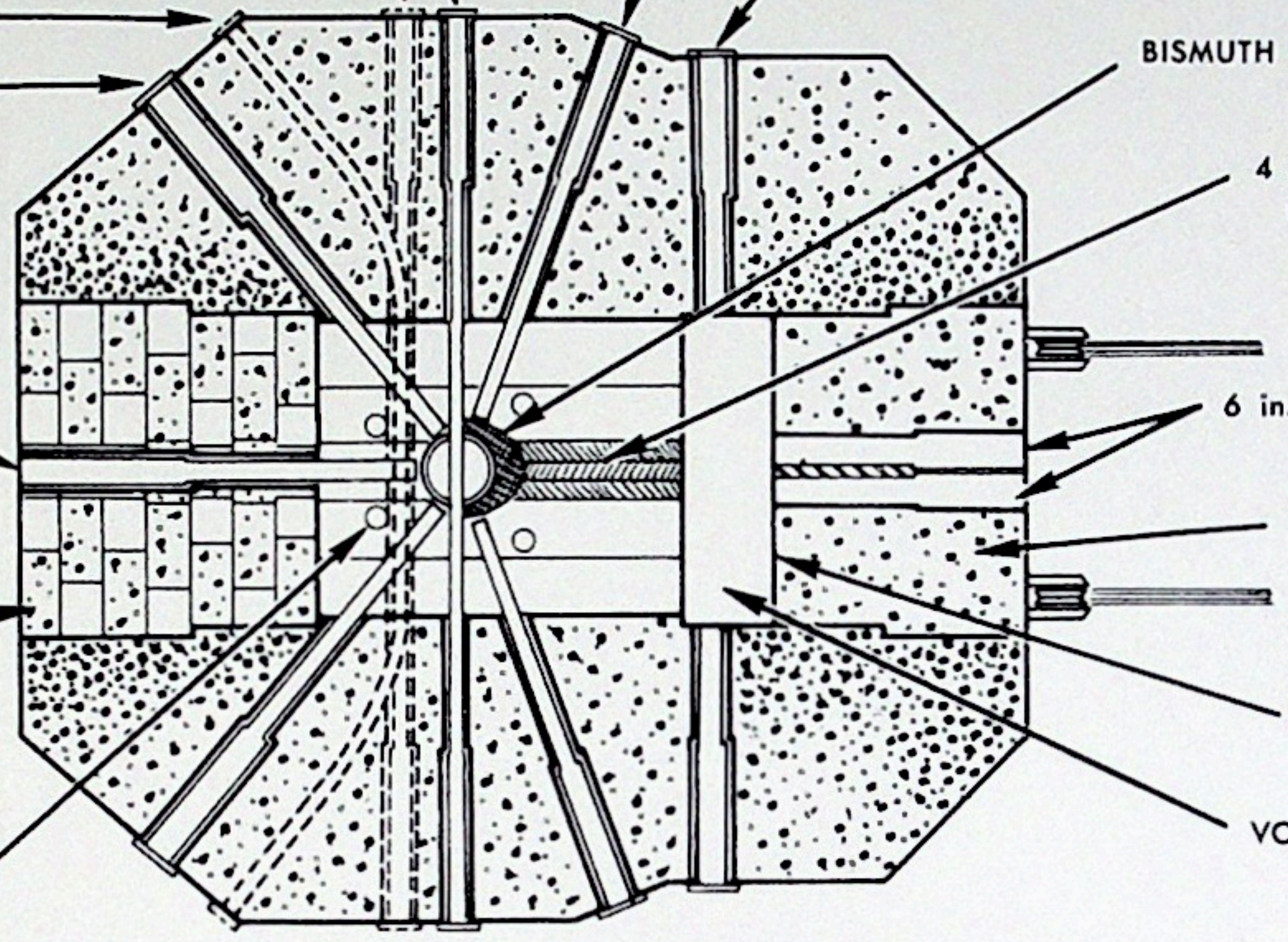
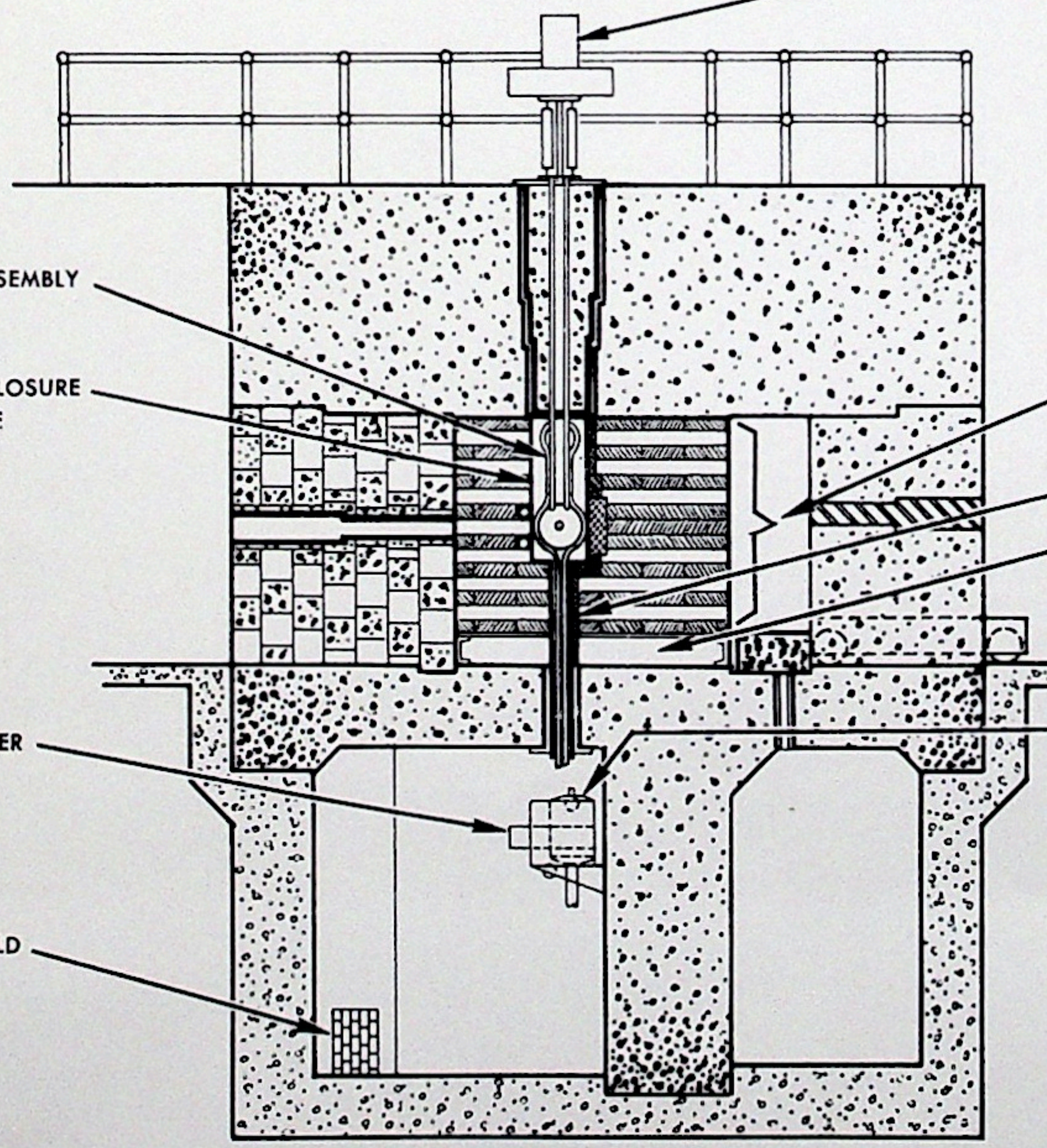


1½ in. DIA. CENTRAL EXPOSURE TUBE
3 in. DIA. BEAM TUBE
2 in. DIA. PNEUMATIC TUBE
6 in. DIA. ACCESS PORT
1½ in. CURVED PNEUMATIC TUBE
BISMUTH SHIELD, ALUMINUM CLAD
4 in. X 4 in. REMOVABLE GRAPHITE STRINGERS
4 in. DIA. BEAM TUBE
6 in. to 4 in. DIA. BEAM TUBE
6 in. SQUARE ACCESS PORTS
ROLLING DOOR
9 in. X 9 in. X 18 in. DENSE-CONCRETE SHIELD BLOCKS
BORAL LINER
VOID SPACE
4 in. DIA. VERTICAL BEAM TUBES



CONTROL – SAFETY ROD DRIVE ASSEMBLY
CORE TANK ASSEMBLY
SECONDARY ENCLOSURE ENVELOPE
GRAPHITE THERMAL COLUMN
LEAD SHIELD
LOCATION OF ION AND FISSION CHAMBER ASSEMBLIES
GAS RECOMBINER
BEAM CATCHER
LEAD SHIELD

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Gas-handling system of the Armour Research Foundation reactor, designed and built by Atomics International, a division of North American Aviation, Inc. This system controls and processes the gaseous products generated within the fuel solution. Hydrogen and oxygen produced by radiolysis are recombined into water, which is then returned to the core tank. Recombination is accomplished by means of a platinum catalyst, which is located within the recombiner tank, shown in the center of the illustration.

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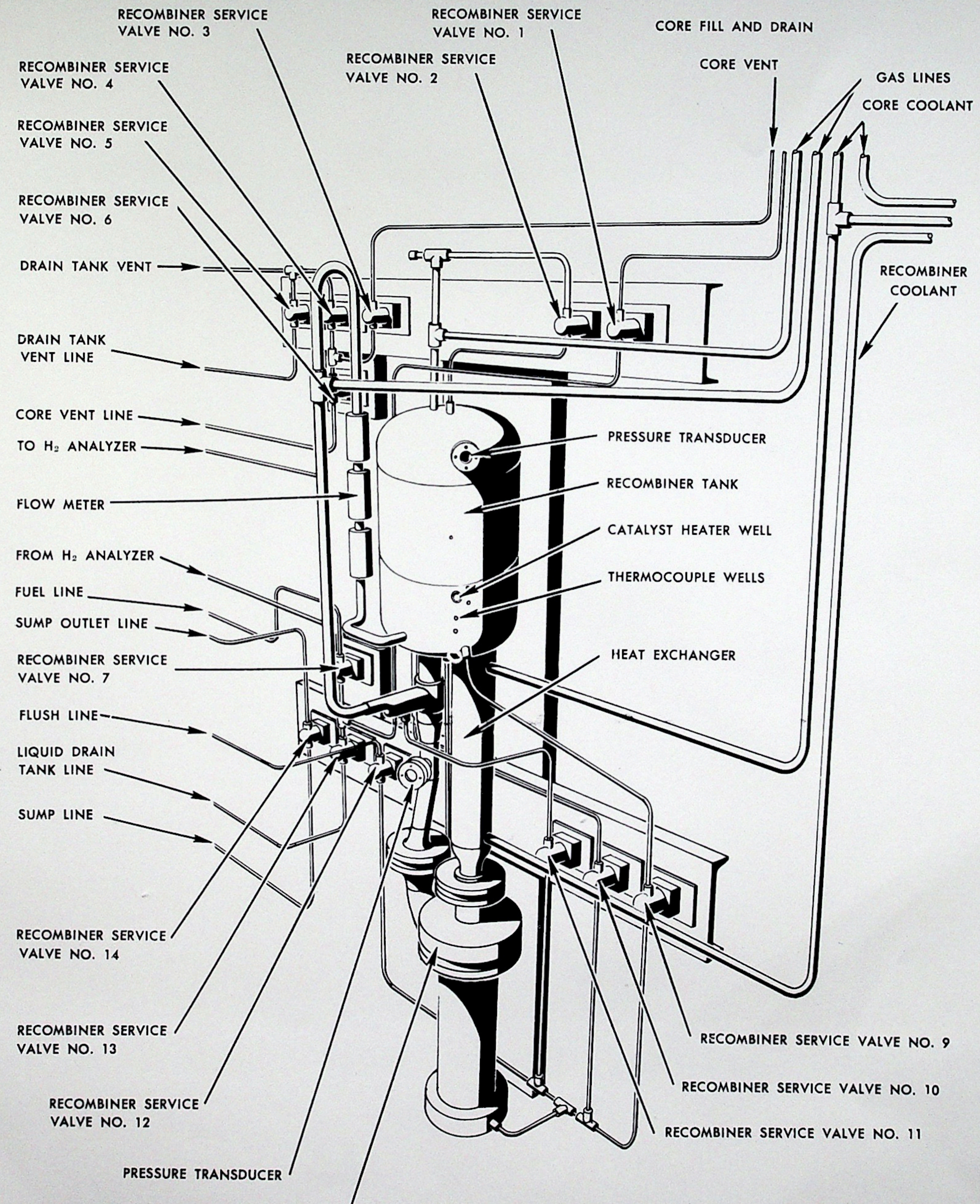
RECOMBINER SERVICE VALVE NO. 3
RECOMBINER SERVICE VALVE NO. 1
CORE FILL AND DRAIN
RECOMBINER SERVICE VALVE NO. 4
RECOMBINER SERVICE VALVE NO. 2
CORE VENT
GAS LINES
CORE COOLANT
RECOMBINER SERVICE VALVE NO. 5
RECOMBINER SERVICE VALVE NO. 6
DRAIN TANK VENT
RECOMBINER COOLANT
DRAIN TANK VENT LINE
CORE VENT LINE
TO H_2 ANALYZER
PRESSURE TRANSDUCER
RECOMBINER TANK
FLOW METER
CATALYST HEATER WELL
FROM H_2 ANALYZER
THERMOCOUPLE WELLS
FUEL LINE
SUMP OUTLET LINE
HEAT EXCHANGER
RECOMBINER SERVICE VALVE NO. 7
FLUSH LINE
LIQUID DRAIN TANK LINE
SUMP LINE
RECOMBINER SERVICE VALVE NO. 14
RECOMBINER SERVICE VALVE NO. 13
RECOMBINER SERVICE VALVE NO. 9
RECOMBINER SERVICE VALVE NO. 10
RECOMBINER SERVICE VALVE NO. 12
RECOMBINER SERVICE VALVE NO. 11
PRESSURE TRANSDUCER
CANNED ROTOR PUMP